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FINAL REPORT

EFFECTS OF FREEZING RATE, STORAGE TEMPERATURE,  
TEMPERATURE ABUSE AND STORAGE TIME ON  
SENSORY, CHEMICAL, INSTRON AND YIELD  
PROPERTIES OF BEEF ROASTS

PREPARED FOR THE

U.S. ARMY NATICK RESEARCH AND DEVELOPMENT LABORATORIES  
NATICK, MASSACHUSETTS 01760

AND THE

FOOD QUALITY ASSURANCE BRANCH  
MARKET RESEARCH AND DEVELOPMENT DIVISION  
AMS, USDA

BY THE

MEAT SCIENCE RESEARCH LABORATORY  
AGRICULTURE RESEARCH SERVICE  
U.S. DEPARTMENT OF AGRICULTURE  
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## ACKNOWLEDGEMENTS

In a project of this size (one of the largest ever undertaken by the Meat Science Research Laboratory) there are obviously many individuals and organizations to acknowledge for their assistance and support. The task of completing all analyses of this project on the very strict deadlines would never have been achieved without all the dedication and hard work of Kathleen Leddy, Marilyn Stanfield, Sue Douglass, Mary Dunn and Janice Callahan. Also, special appreciation is extended to all the students who filled in the "gaps," often on weekends to help with this project. We greatly appreciate the many hours spent by Dr. L. W. Douglass and his staff in performing the statistical analysis. We gratefully acknowledge the financial support of John Secrist and Joe Smith of the Natick Laboratories and Joan Luck Russ and Curtis Green of AMS. The members of the taste panels deserve a special recognition for participating throughout this long project and we especially appreciate the efforts of BARC refrigeration and surveillance personnel for insuring that the project temperature requirements were maintained. Special thanks is extended to: (1) Transportation and Refrigeration Research Foundation-University of Maryland for providing facilities for freezing, (2) the Department of the Army for providing storage freezers, and (3) Esskay Meat Processing Company for processing the product. Finally, we would thank the Word Processing Center for their assistance and especially Judy Adams and Ralphine Andrews for their special efforts in typing this report.

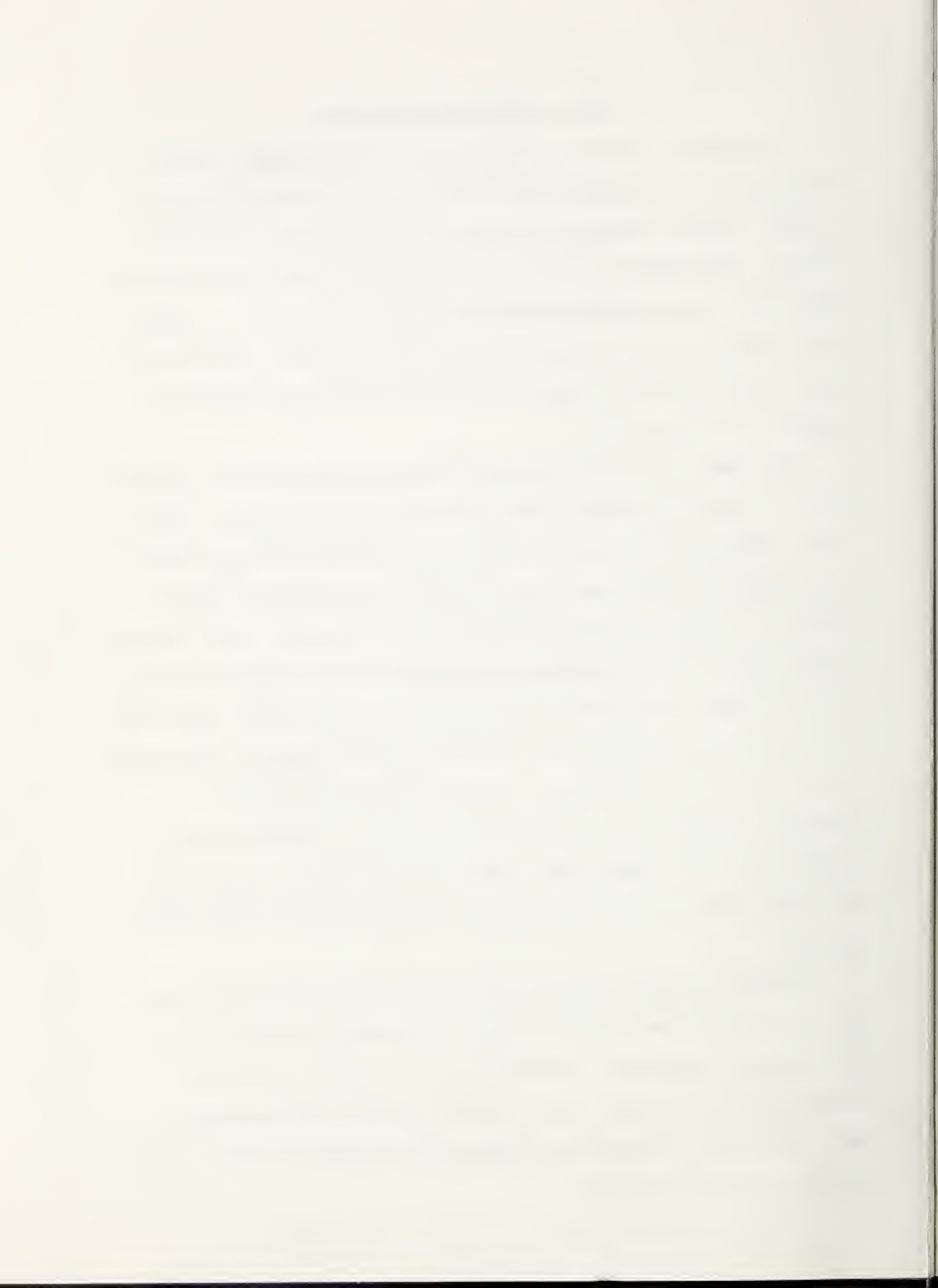


## OVERALL SUMMARY AND CONCLUSIONS

In contrast to the other products (ground beef in several forms), characteristics of beef roasts were not affected as much by the factors studied. Freezing rate seldom, directly and consistently, affected the results. Advancements in storage time up to twelve months and the use of +20°F final storage temperature most often were responsible for changes in roast properties when they occurred. The use of different carcasses for each freezing rate did not appear to create as much variability as was thought prior to the study.

While many interactions were found (substantiated by the 307 tables) most involved very few real, logical and consistent differences. Muscle color, tenderness and total roast weight loss from before freezing until after cooling of cooked roasts were variables that underwent the most change as a result of imposing the variables of the project. Once frozen, roasts tended to have more dark red and blackish purple pigmentation than before freezing. Upon thawing these immediately frozen roasts, there was less moderately cherry red color, but more very dark red color than was the case on roasts prior to freezing. The use of +20°F final storage temperature produced less slightly dark red and more very dark red and blackish purple than 0 and -10°F, especially as storage time progressed. For thawed roasts, longer storage time resulted in more moderately cherry red color.

Freezing in itself produced considerable surface discoloration, and this discoloration continued with advancing storage time and the use of +20°F storage temperature. For thawed roasts, there was a definite tendency for roasts frozen to 0°F in 96 hr to have more discoloration. More freezer burn was detected as storage time progressed especially for roasts frozen to 0°F in 96 hr.



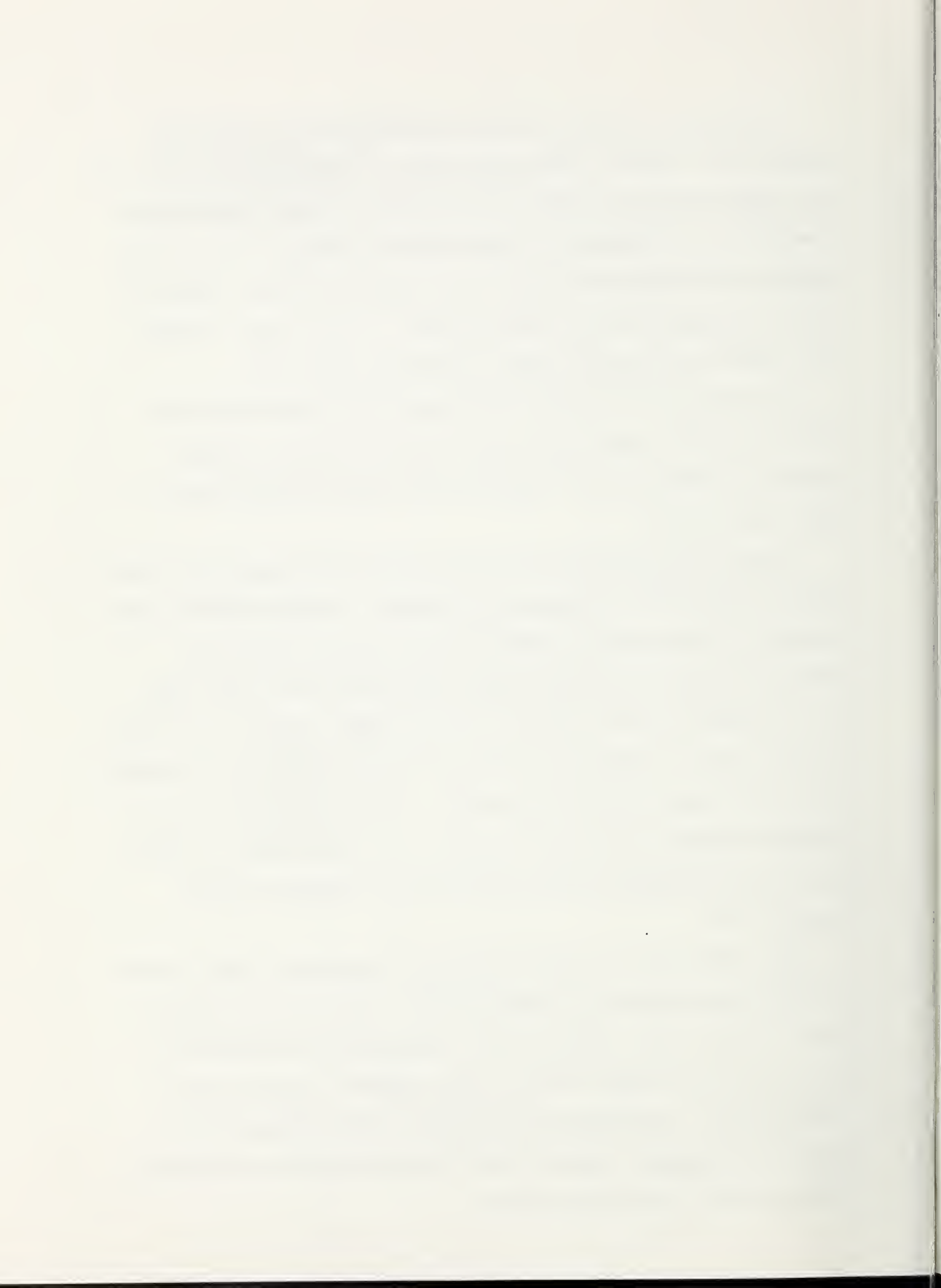


The presence of off-odor (largely rancidity) increased some with storage time. Generally, TBA values remained low throughout the study, but were slightly higher for roasts stored at +20°F compared to the other two temperatures. The intensity of roast beef flavor underwent only a slight reduction with progressive storage time. More rancidity was detected in flavor evaluations for roasts stored at +20°F. Rancid flavor increased with storage and appeared to replace "sour" as a flavor note.

Juiciness was reduced just by freezing and very slight reductions occurred with +20°F storage and longer storage. There was a gradual reduction in tenderness with storage which was much more pronounced in roasts held at +20°F.

Textural values obtained with the Universal Instron machine were often variable respective to the design of the project. For some reason, roasts evaluated at nine months from the 0°F in 72 hr rate were often much different in Instron values than other freezing rates and storage times. While the modulus values for the 0°F in 72 hr frozen product at nine months were quite low, the same could be said for this freezing rate at six months if the roasts were initially stored at 0°F. Fail energy values for cores increased somewhat with storage time, while fail energy values for slices were increased slightly for roasts frozen to 0°F in 96 hrs vs other freezing rates.

Total weight loss for roasts from before freezing until after cooling of cooked roasts generally was between 30-35%. This loss was lowest for roasts that were never frozen and thus, subsequently never subjected to storage. The total weight loss was slightly higher if roasts had been stored at +20°F. The process of just freezing itself usually produced slight gains in weight. The use of +20°F storage temperature substantially increased weight losses during storage.



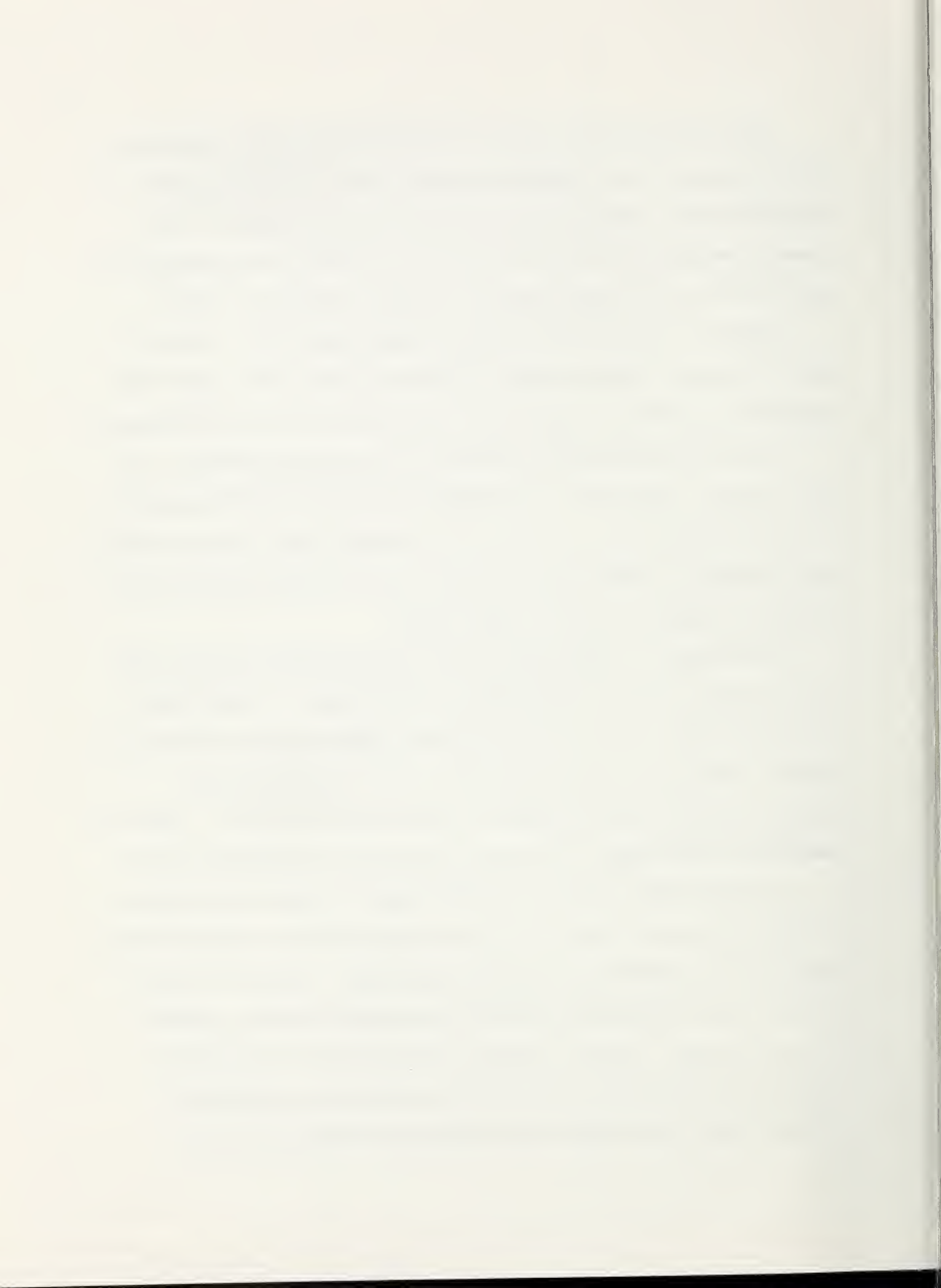
Thaw losses were lowest among frozen roasts right after freezing and before storage. This is somewhat surprising since at that time, more weight (moisture) should be available for loss during thawing. Also, somewhat unexpectedly (in view of other weight losses during storage), the use of +20°F final storage temperature slightly elevated thaw losses.

Advances in storage time gradually reduced cooking loss. Also, as would be expected, longer storage times and the use of +20°F reduced the evaporative component of cooking loss and elevated the drip loss component.

Storage reduced the percent moisture in raw roasts, generally, from 1-3%. However, percent fat in raw roasts was somewhat variable according to the variables studied. Percent fat was somewhat higher following twelve months storage for roasts held at +20°F. Percent moisture and fat values followed no consistent trend in cooked roasts.

In conclusion, it would appear that freezing rates of the range used in this study do not exert many effects on beef roasts. It would appear obvious that +20°F is not a suitable storage temperature certainly past six months. There was no clear evidence that -10°F storage temperature produces that much more improvement in product quality over 0°F. Also, the temperature abuse process did not play a major role in affecting results.

In terms of when storage time should cease for a beef roast product, it should be realized that all of the subcutaneous fat was removed from the roasts prior to freezing for standardizing purposes. Had this fat been left on, in all likelihood, rancidity-type problems would have occurred earlier in storage. However, improved packaging over the placement of roasts in a polyethylene bag and folding the top down, would probably produce longer storage times before deterioration became noticeable.



## INTRODUCTION

Freezing as a processing procedure is often a necessity for meat products that must undergo transcontinental and oceanic distribution or must be purchased far in advance of consumption due to supply, price and demand. These situations are frequently prevalent in USDA's purchase programs of ground beef for the school lunch program and DOD's procurement of meat products for military establishments. In order to maximize storage life, certain specifications regarding freezing rates, storage temperatures, packaging materials, raw material wholesomeness are applied.

One of the specifications required in the processing of meat products for government procurement deals with freezing rate. Prior to 1982, the requirement was that the product must be frozen to 10°F in 72 hr. Based on a variety of information sources, this requirement was changed in 1982 to 0°F in 72 hr, which reflects a faster rate of freezing. There were some representatives from industry who indicated that this faster freezing rate imposed hardships on their operations and placed them in non-competitive positions. However, there are others (processors and end-users) who maintain that faster freezing rates improve product quality.

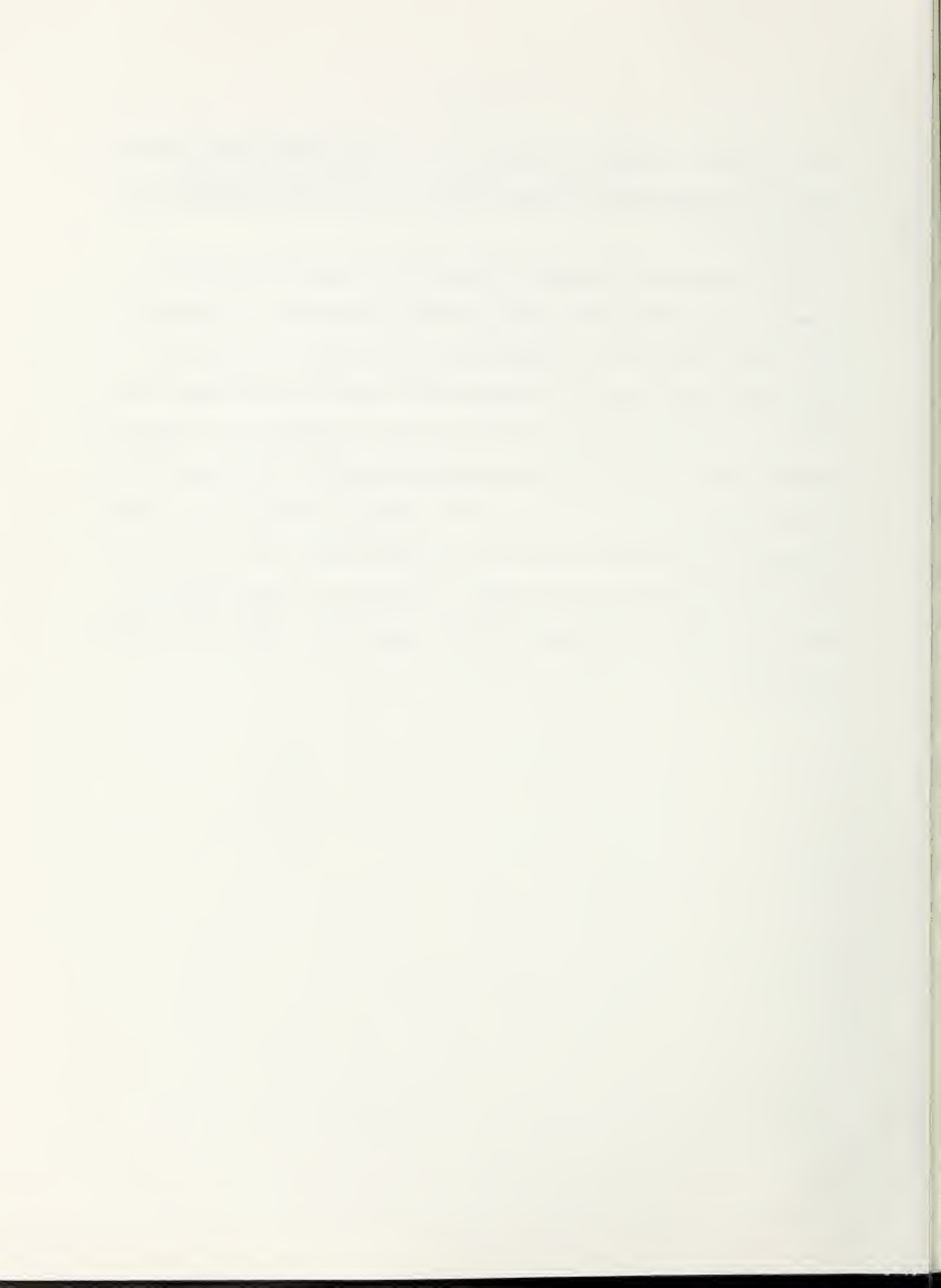
In terms of defining what freezing rates were actually being used in industry, a nationwide survey of meat freezing operations was conducted. The survey indicated that a wide range in freezing rates was being practiced; some faster than the 0°F in 72 hr requirement, some slower. Thus, it was decided to evaluate for this project, four different freezing rates; 0°F in 24, 48, 72 and 96 hr. In preliminary studies, it was determined that wide ranges in time (often as much as 36-48 hr to reach 0°F) exist within a pallet load of meat in terms of when 0°F is achieved.



Thus, in order to achieve the uniformity in freezing rate required for this study, it was necessary to freeze product out of the boxes, spaced out on wire mesh racks.

Due to the lack of supportive literature to answer the effects of freezing rate on meat product characteristics, especially in conjunction with frozen storage time and temperature, this project was inaugurated. Four products (beef roasts, bulk ground beef with soy, ground beef patties with soy, ground beef patties without soy) were subjected to the above four freezing rates, two initial storage temperatures (0°F, -10°F), three final storage temperatures (0°F, -10°F, +20°F), temperature abuse of 4 hr at 85°F following 45 and 59 days of storage, and storage times of 0, 6, 9, 12, 18 and 24 months depending on the product. Evaluations included shelflife, microbial, sensory, instrumental texture, weight loss, chemical and cooking properties.







## MATERIALS AND METHODS

### I. General

The overall design of the project is given in Figure 1. Due to the need to freeze the product out of boxes, it took four weeks of a month to put up a given product. In order to reduce possible sources of variation in beef roasts, selection of the top rounds for the project occurred at the packing plant. Top rounds from paired right and left sides of USDA Choice carcasses were selected. The carcasses providing rounds were similar in weight, external fat cover, muscling and marbling (lower 1/3 of the grade). Each top round was cut into 3-pound roasts which were distributed within the various storage times for a particular freezing rate.

#### A. Freezing Rates: 0°F in either 24, 48, 72 or 96 hours.

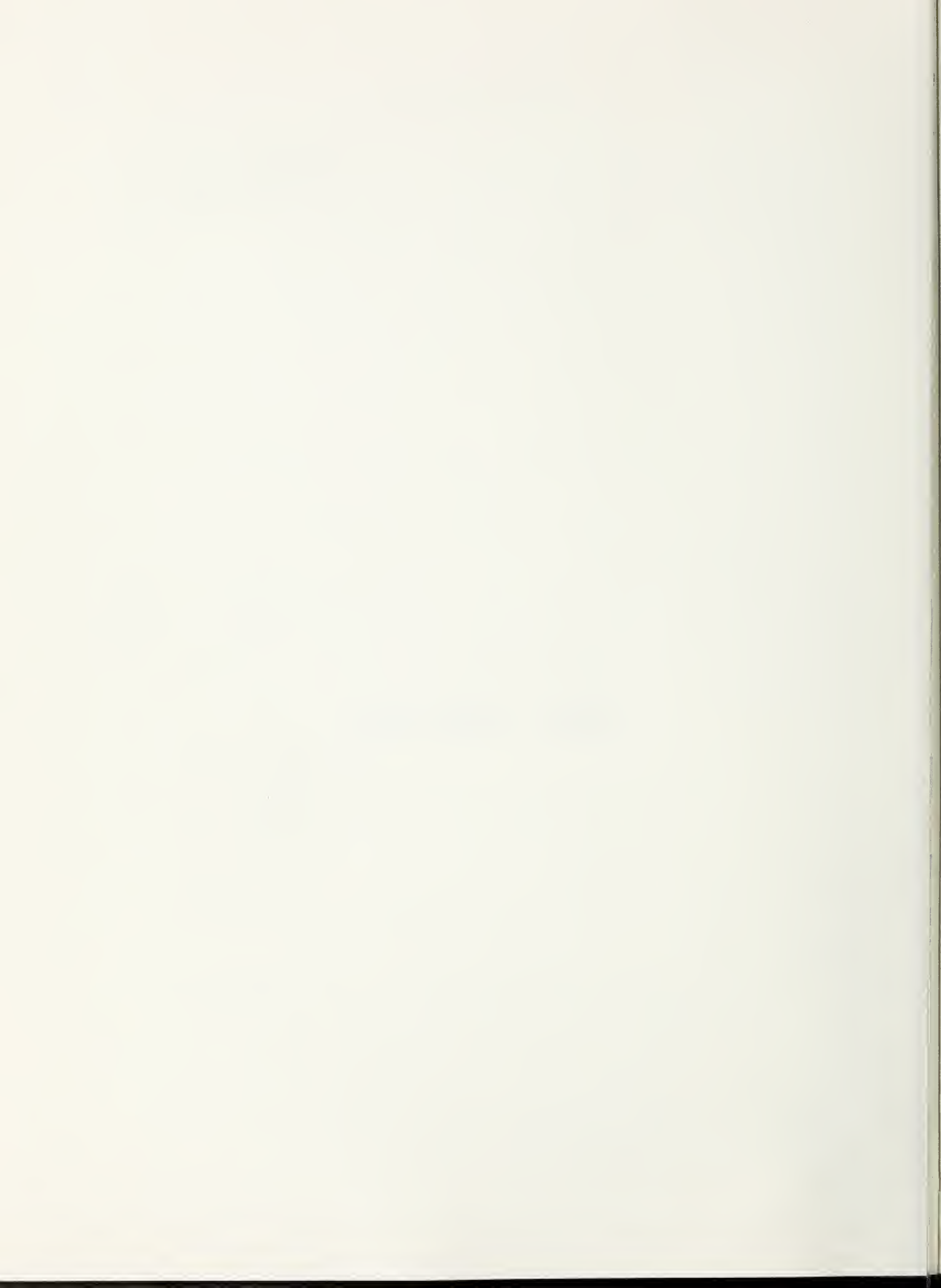
Product was frozen out of boxes on wire racks on shelves placed in freezers of the Refrigeration Research Foundation, University of Maryland. Product was spaced such that air flow was present and consistent between the various samples. Approximately 37 boxes of product (out of the boxes) were frozen at a time. Product was in 1.5 mil poly bags during freezing. Only minimum air velocity was used in the freezers during freezing to reduce the roast to roast variation in freezing times. The mean freezing curves for all four rates are given in Figure 2. Following freezing, product was reboxed, coded for identification and transported to the Meat Science Research Laboratory.

#### B. Initial Storage: Prior to abuse = 0°F, -10°F temperatures.

For the beef roasts, each box contained the 9 roasts/carcass for two carcasses. After abuse, roasts were regrouped to contain/box, one-half the roasts for all tests that were performed at a given storage time and that had been held at a common storage temperature.

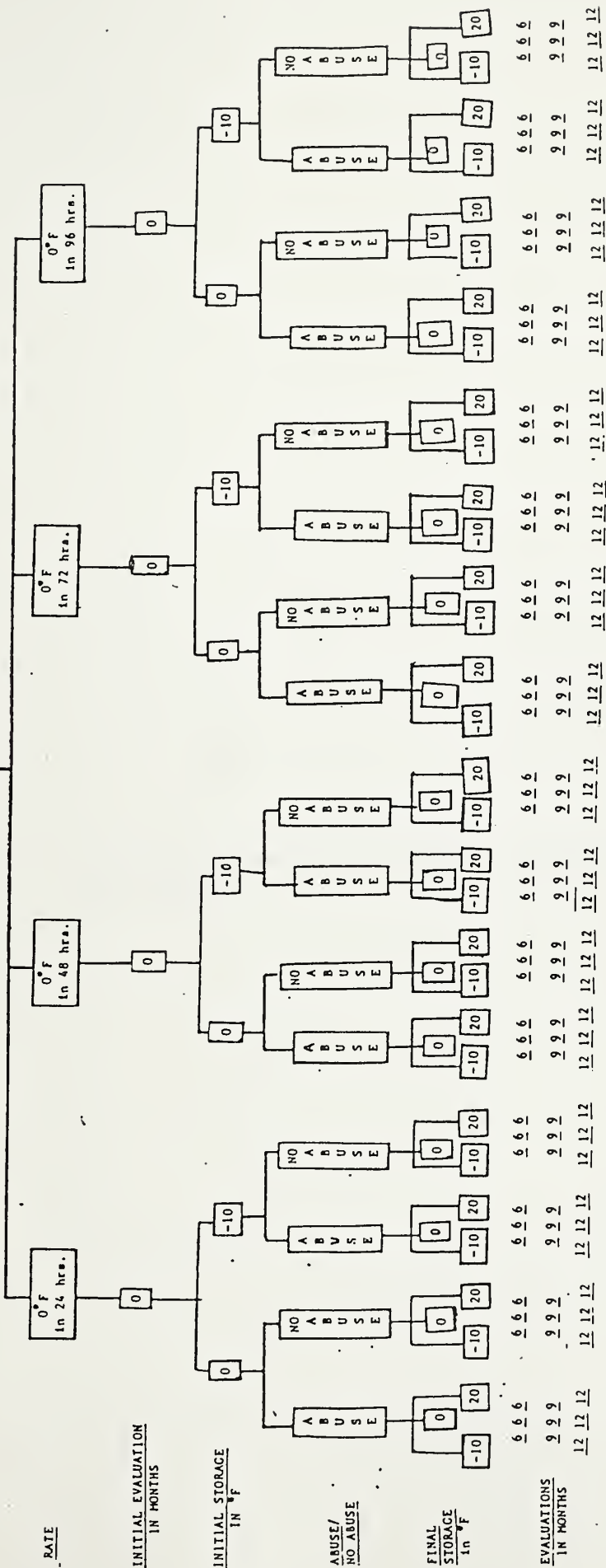


Figure 1. Project design.



PRODUCTS

CBP W/ CSC  
CBP H/O/GSC  
CBB W/ CSC  
OVEN ROAST



KEY

CBP = Ground Beef Patties  
CBB = Ground Beef Bulk  
GSC = Granulated Soy Concentrate  
ABUSE = At days 45 and 59  
4 hrs. at 85°F

MEATS FREEZING PROJECT

MEAT SCIENCE RESEARCH LABORATORY

For the U.S. Army Natick Research and Development Laboratories

January 1983

(FIGURE 1)

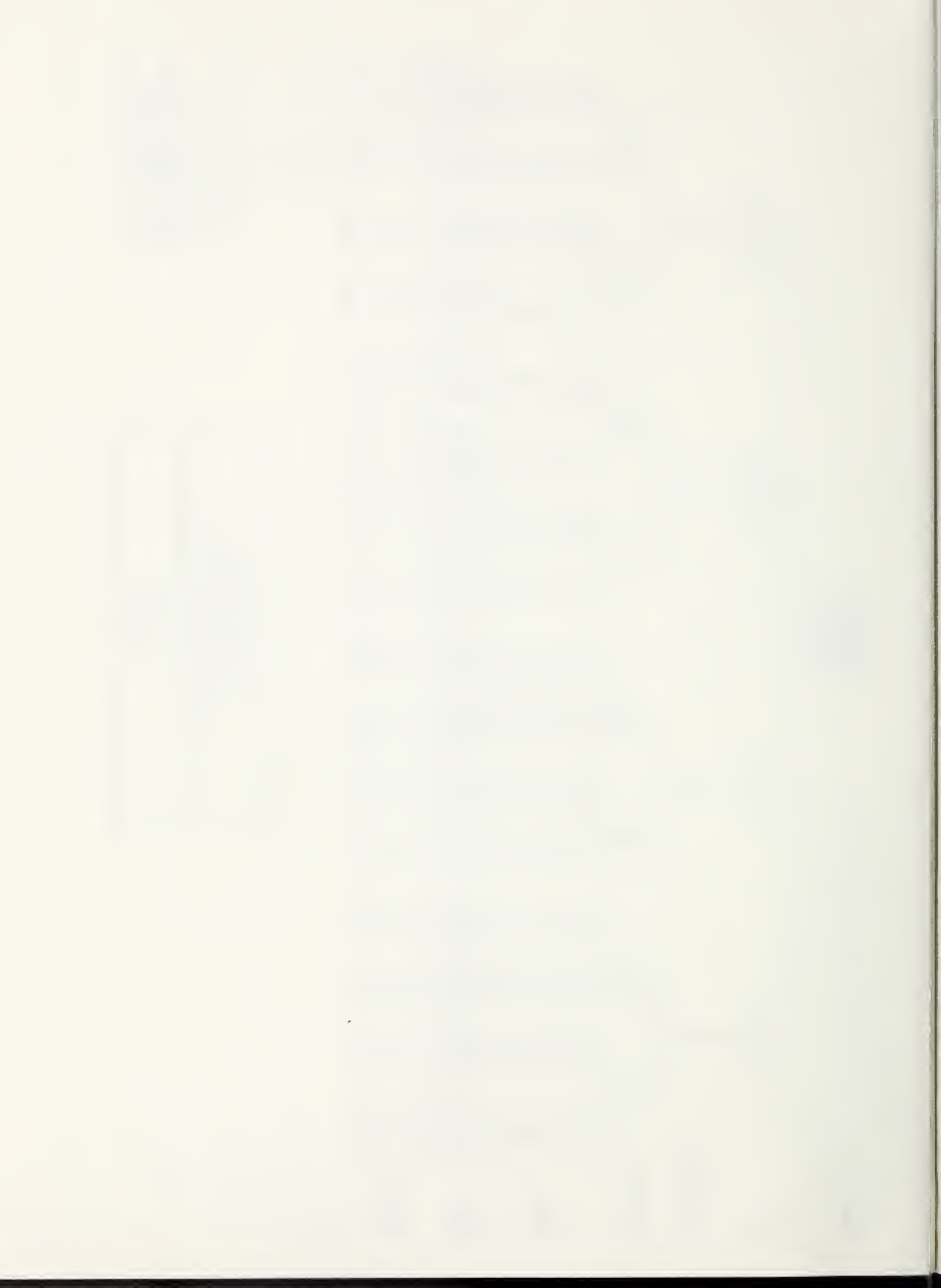
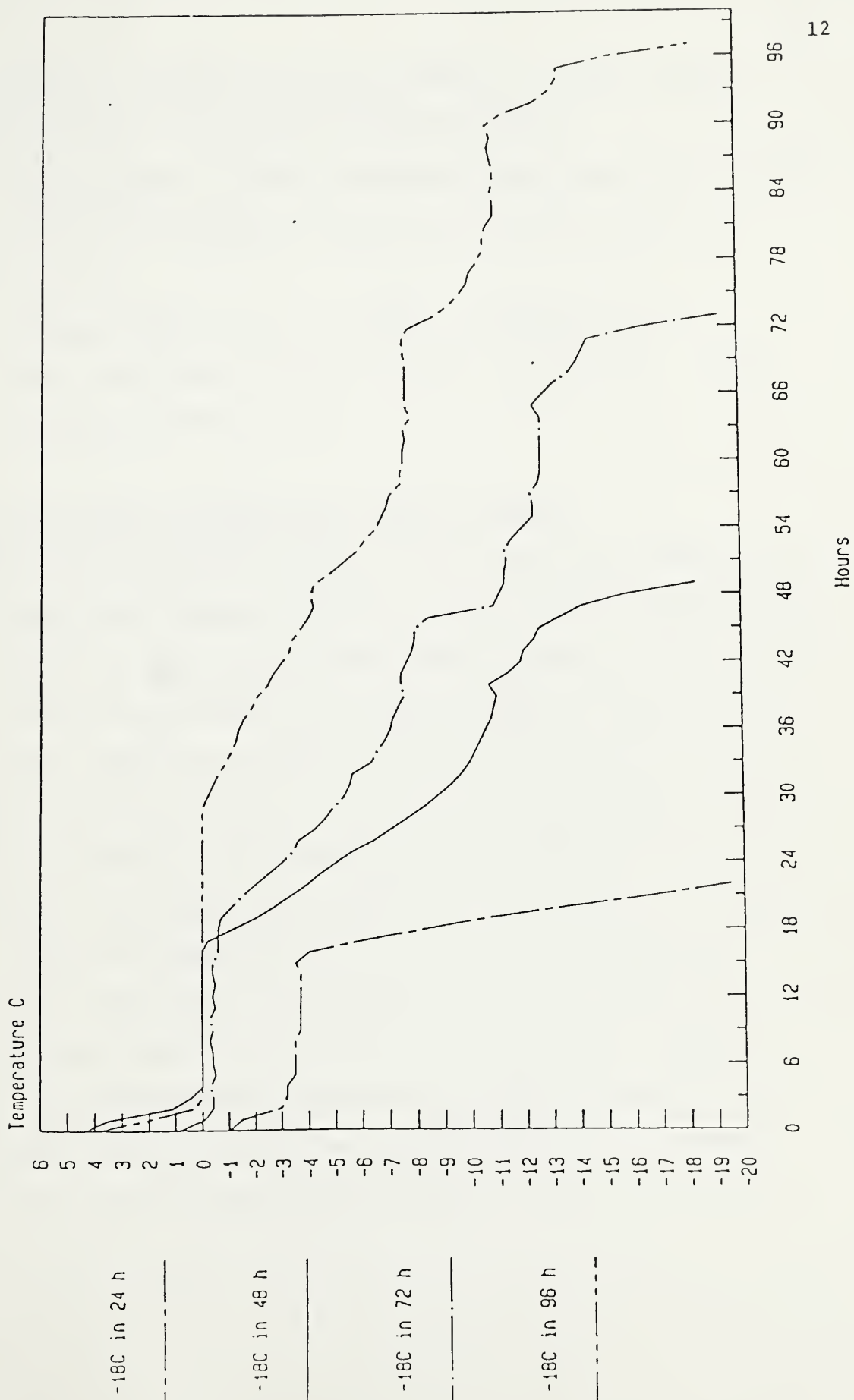


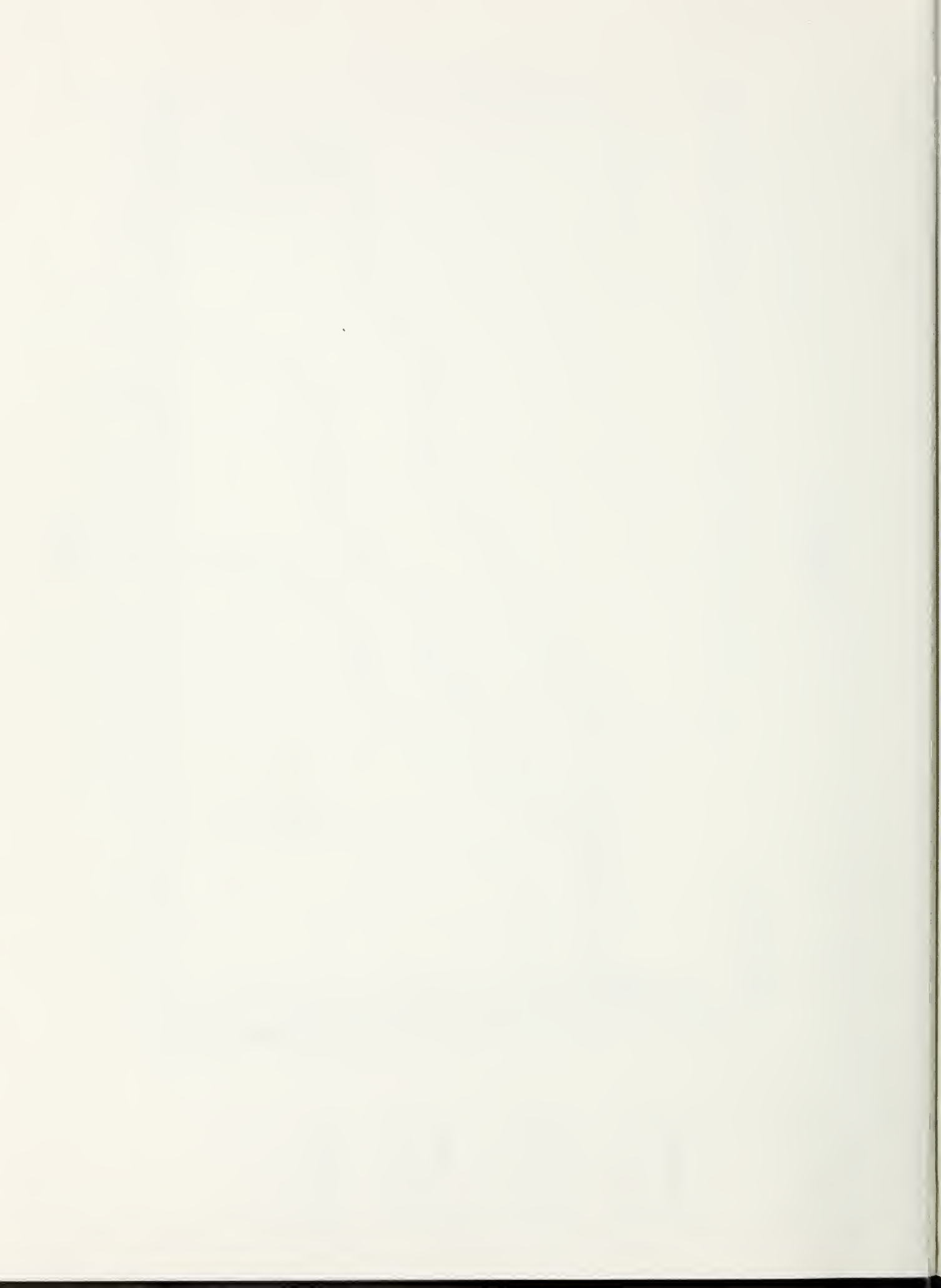
Figure 2. Freezing curves to reach 0°F in 24, 48, 72, and 96 hours for beef roasts.





# ROASTS





C. Abuse: No abuse (best possible handling). Abuse = holding product at 85°F for 4 hrs at 45 and 59 days of storage.

D. Final Storage: Following temperature abuse, roasts were regrouped from all treatments and stored in boxes at one of three temperatures = +20°F, 0°F, -10°F.

E. Storage Times: 0, 6, 9, 12 months. Two boxes for each combination at each storage time were subjected to evaluation. Product identity was kept separate per box.

## II. Sample Identity, Storage, and Product Evaluation.

Before the project was started, carcass identification numbers from each freezing rate (n=40) were assigned to one of five research procedures (yield/shelflife; raw chemical; cooked chemical; sensory; Instron). Roasts fabricated from a given carcass were always evaluated for the same test, thus, carcass identity was maintained throughout the 12-month evaluation period for each test procedure. Following 6, 9, and 12 months of frozen storage, 40 roasts total (eight roasts from eight different carcasses for each of the five procedures) were evaluated for each of the four freezing rates. The twelve roasts/carcasses were allocated for evaluation as follows: one before freezing, one immediately following freezing, one at 6, 9, and 12 months within each final storage temperature for a specific initial storage temperature-temperature abuse combination and one extra. Thus, roasts from a given carcass were not distributed across freezing rate, initial storage temperatures and temperature abuse or not abuse.



### III. Cooking Methodology

Frozen roasts were thawed at least 36 hours at 4°C prior to all analyses. Thawed roasts were placed on wire racks within stainless steel roasting pans. Roasts were cooked at 162°C to an internal end-point temperature of 68°C (General Electric CN 52). Oven and internal roast temperatures were monitored by means of copper constantan thermocouples attached to a temperature recording device (Honeywell Multipoint 112). With the exception of roasts cooked for sensory analysis, all cooked roasts were cooled to 50°C prior to sampling.

### IV. Sampling and Evaluation

A. Percent Yield. Product losses and yields were determined by weight loss from fresh to frozen, during storage, frozen to thawed and thawed to cooked state. Drip, evaporative and cooling losses were also determined.

B. Shelflife Evaluation. Frozen roasts, within the bag, were evaluated for evidence of shelflife deterioration by a trained team of staff members. Color of lean, percent frost, and percent surface discoloration were evaluated on frozen roasts. Thawed roasts (without the bag) were evaluated for the presence of off-odors, lean color and surface discoloration. Lean colors were evaluated by means of color chips, typical of lean meat colors, assigned numerical identification codes (Beef Carcase Classification, Western Australian Department of Agriculture) whereby 8 = light grayish red, 0 = very dark purplish black. Percent frost and percent surface discoloration were evaluated on a seven-point scale (1 = greater than 90 percent of the surface covered in frost or discolored;



7 = 0 percent frost or surface discoloration). Odor was evaluated on a four-point scale (1 = extreme off-odor; 4 = no off-odor). Scoring systems are given in Table A.

C. Chemical Analyses. To minimize sample waste, one thawed roast provided samples for three chemical analyses. Thawed, uncooked roasts were trimmed of extraneous muscles and intermuscular fat prior to sampling. Analyses were conducted within four hours of sampling.

1. Expressible juice. Two core samples (1.25 cm diameter)/per roast were excised from the center of each roast, placed in ziplock plastic bags, and allowed to warm to 25°C before analysis. Expressible juice was determined from each core sample according to the procedures of Wierbecki and Deatherage (1958) with modifications described by Briskey et al. (1959).
2. Two-Thiobarbituric Acid Analysis. Two cross-section slices (0.60 cm thick) were removed from two different locations within the muscle of each roasts. The entire outer surface and interior of the slices were represented in the sample. TBA analysis was conducted in duplicate on one sample from each slice according to the distillation procedure of Tarlaogis et al. (1960).
3. Fat and Moisture Analysis. The remaining portion of the muscle was cut into cubes, ground once through a .96 cm plate, then ground twice (.32 cm) for fat and moisture determinations AOAC (1980). Percent moisture was determined by weight loss of three five-gram samples/roast following 18 hours of drying at 100°C in a vacuum oven (Precision 524). Percent fat was determined by weight loss of three five-gram samples following 16 hours of Soxhlet extraction with petroleum ether.





Table A. Scoring systems for Shelflife Evaluation

Surface Discoloration and Freezer Burn	Color of Lean <sup>a</sup>	Off-odor
7 = 0%	8 = Light grayish red	4 = No off-odor
6 = <10%	7 = Very light cherry red	3 = Slight off-odor
5 = 11-25%	6 = Moderately light cherry red	2 = Moderate off-odor
4 = 26-50%	5 = Cherry red	1 = Extreme off-odor
3 = 51-75%	4 = Slightly dark red	
2 = 76-90%	3 = Moderately dark red	
1 = >90%	2 = Dark red	
	1 = Very dark red	
	0 = Dark purplish black	

<sup>a</sup>Photographic scale adapted from Western Australian Beef Carcase classification system.



Cooked roasts were sampled after cooling to 50°C and analyzed similarly to raw roasts for expressible juice and percent fat and moisture. TBA analysis was not conducted on cooked roasts.

D. Sensory Analysis. An eight-member descriptive attribute panel was trained according to the procedures of Cross et al. (1978). Panelists evaluated sliced roast beef for tenderness, juiciness, beef flavor intensity, the presence of other flavors and their intensities, and the amount of connective tissue. These attributes were evaluated on an eight-point structured scale (8 = extremely tender, juicy, intense in flavor, and no connective tissue; 1 = extremely tough, dry, bland and abundant in connective tissue). Scoring systems are presented in Table B.

Roast beef slices were cut with a slicing machine (U.S. Berkel) perpendicular to the muscle fibers. Slices were approximately one mm thick. Each panelist evaluated two pieces (3.1 cm<sup>2</sup>) from two different slices per sample. Each piece was cut to include 50 percent outside and 50 percent inside edge areas of a slice. Every effort was made to keep the samples hot during serving. Panelists received warm water and unsalted melba toast between samples. Taste panel sessions were conducted during each storage evaluation period. Two, four-sample sessions were held twice a week until each treatment had been replicated twice. Each day's double session took approximately one hour. A 10-minute break was provided between sessions. Serving order was completely random within a session.



Table B. Scoring systems for sensory evaluation

<u>TENDERNESS</u>	<u>JUICINESS</u>	<u>CONNECTIVE TISSUE AMOUNT</u>
8 - Extremely tender	8 - Extremely juicy	8 - None
7 - Very tender	7 - Very juicy	7 - Practically none
6 - Moderately tender	6 - Moderately juicy	6 - Traces
5 - Slightly tender	5 - Slightly juicy	5 - Slight
4 - Slightly tough	4 - Slightly dry	4 - Moderate
3 - Moderately tough	3 - Moderately dry	3 - Slightly abundant
2 - Very tough	2 - Very dry	2 - Moderately abundant
1 - Extremely tough	1 - Extremely dry	1 - Abundant

<u>BEEF FLAVOR INTENSITY</u>	<u>OTHER DETECTABLE FLAVORS</u>
8 - Extremely intense	Sour
7 - Very intense	Bitter
6 - Moderately intense	Metallic
5 - Slightly intense	Sweet
4 - Slightly bland	Rancid
3 - Moderately bland	Putrid
2 - Very bland	Salty
1 - Extremely bland	Other



E. Instron Textural Measurements. Two roasts from each treatment/storage time were cooked and cooled to room temperature prior to evaluation. Shear force was determined on six cores (1.25 cm)/roast by means of a Warner Bratzler shearing device attached to an Instron 1122. Shear force measurements were also determined using a straight edge shear blade on six individual slices (3.1 cm<sup>2</sup>) folded to a double thickness. Instron measurements included peak load, Newton's, modulus and fail energy.

F. Statistical Analyses. Data were reduced and subjected to analyses of variance which included evaluations for freezing rate, initial storage temperature, final storage temperature and temperature abuse within storage times and all appropriate interactions. Storage time comparisons included all the above sources of variation in individual time comparisons involving values obtained immediately following freezing with a particular storage time. Also, adjacent storage times (six vs nine months, nine vs twelve months, etc.) were also compared. Data were evaluated and adjusted for additional analyses based on carcass to carcass variation and variation due to grouping of carcasses for particular freezing rates.

The mean separation technique of Tukey's HSD was employed. In the case of color and flavors, Chi-square was utilized on frequency distributions for main effects and selected treatment combinations. At the beginning of each section on new variable data in the Results and Discussion, a general overall table illustrating means and standard deviations is provided. The following tables within the sections indicate the mean differences and standard errors.





## RESULTS AND DISCUSSION

Color scores expressed as frequency percentages in Table 1 indicate that some differences existed among freezing rates (different animals in this case) before freezing was ever initiated. The major differences appear to be the occurrence of more slightly dark red and moderately dark red with less very light red and light grayish red in the roasts selected for the 0°F in 48-hr rate compared to the other three rates.

Color frequency values according to the various combinations of freezing rate and final storage temperature for roasts stored six months are presented in Table 2. Unlike before freezing, roasts frozen to 0°F in 48 hr were lighter in color than roasts frozen at the other three rates. There was less slightly dark red in product stored at +20°F, but more very dark red and blackish purple compared to the other two storage temperatures.

At twelve months of storage temperature, frozen abused product displayed less of the lighter colors and more of the darker colors compared to nonabused product (Table 3).

As storage increased, (six to twelve months) the incidence of dark red color increased for roasts stored at +20°F but slightly decreased for roasts stored at -10°F and 0°F (Table 4). The highest frequencies of this pigment occurred just before and after freezing of roasts. More rapid freezing (0°F in 24 hr) decreased the incidence of this pigment, while the opposite was true for slower rates of freezing.

Blackish purple was never found before freezing, but was frequently noted immediately following freezing of roasts (Table 5). Storage at +20°F tended to increase the occurrence of this pigment.



Table 1. Color scores assigned to beef roasts prior to freezing<sup>a</sup>

Color	Freezing rate, hours to 0°F			
	24	48	72	96
Light grayish red	4.07	0.84	4.13	3.23
Very light cherry red	17.07	10.92	19.83	20.16
Moderately light cherry red	23.58	22.69	19.83	20.16
Cherry red	17.07	13.45	14.05	8.06
Slightly dark red	20.33	26.05	18.18	15.32
Moderately dark red	14.63	21.85	15.70	18.55
Dark red	3.25	3.36	8.26	10.48
Very dark red	0.00	0.84	0.00	4.03

Chi-square = 35.68;  $P < .0238$

<sup>a</sup>Values are percentages of scores assigned within a freezing rate.

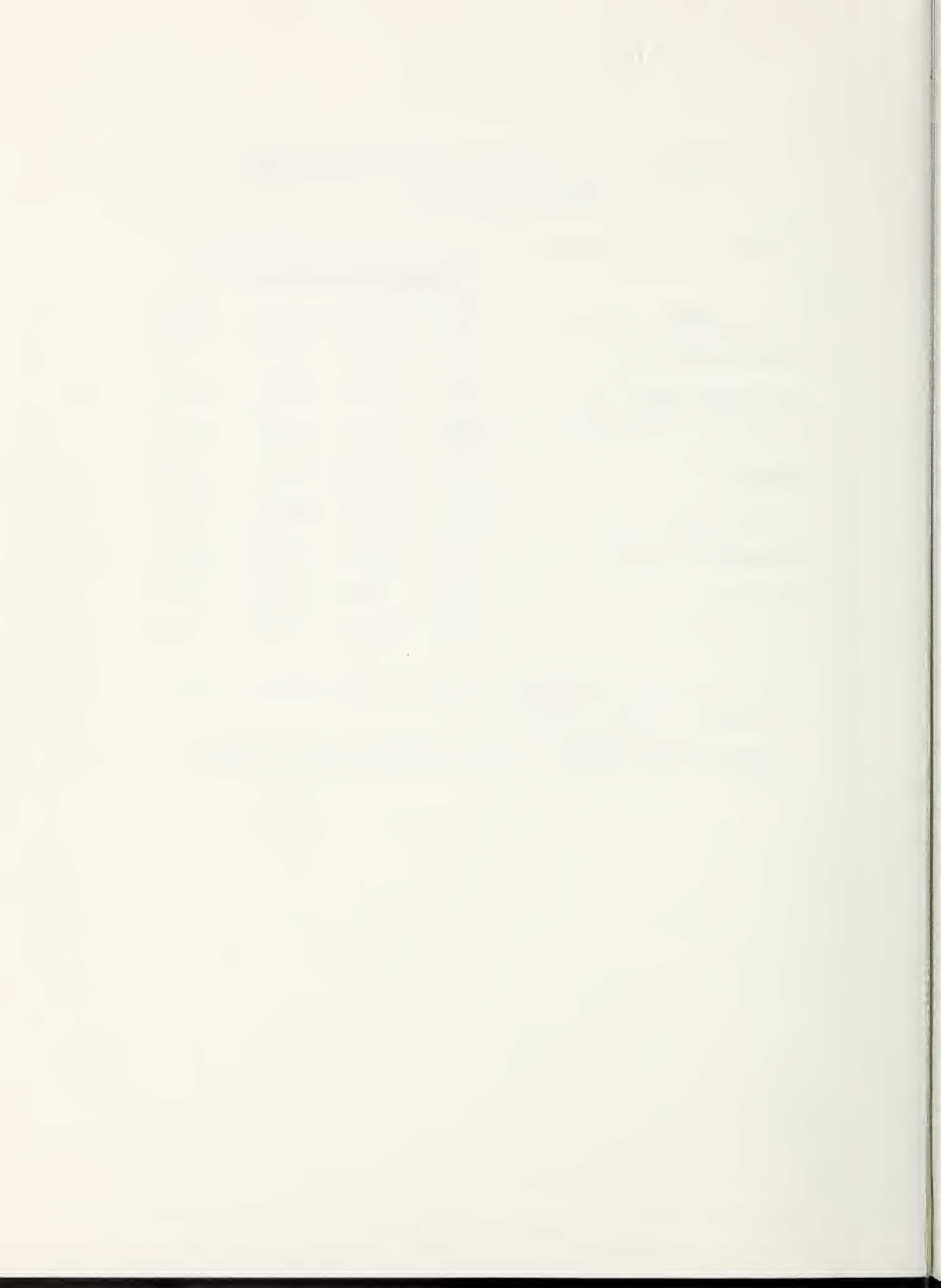


Table 2. Color scores assigned to frozen beef roasts according to freezing rate and final storage temperature following six months storage<sup>a</sup>

Rate, hr to 0°F	Final storage temperature, °F	Color						
		Very light cherry red	Moderately light cherry red	Cherry red	Slightly dark red	Moderately dark red	Dark red	Very dark red
24	-10	0.0	0.0	2.44	15.85	18.29	24.39	24.39
	0	0.0	0.0	1.20	13.25	20.48	24.10	24.10
	+20	0.0	0.0	0.0	7.89	19.74	23.68	25.00
48	-10	0.0	4.82	3.61	10.84	18.07	22.89	22.89
	0	6.06	10.10	2.02	14.14	10.10	19.19	20.20
	+20	1.27	3.80	3.80	8.86	16.46	20.25	25.32
72	-10	0.0	3.13	0.0	17.19	15.63	23.44	23.44
	0	0.0	0.0	2.94	16.18	17.65	22.06	23.53
	+20	0.0	0.0	0.0	9.43	15.09	22.64	30.19
96	-10	0.0	0.0	1.75	7.02	19.30	28.07	28.07
	0	0.0	0.0	0.0	9.68	16.13	24.19	25.81
	+20	0.0	0.0	0.0	3.70	9.26	27.78	29.63

Chi-square = 121.89,  $P < .0009$

a values are percentages of scores assigned within a rate - final storage temperature combination.



Table 3. Color scores assigned to frozen beef roasts according to temperature abuse following twelve months storage<sup>a</sup>

Color	Temperature abuse	
	T	N
Very light cherry red	1.01	.47
Moderately light cherry red	4.32	9.48
Cherry red	2.59	3.79
Slightly dark red	17.58	21.80
Moderately dark red	19.45	18.96
Dark red	23.30	23.70
Very dark red	21.04	18.01
Blackish purple	10.66	3.79

Chi-square = 19.86,  $P < .0059$

<sup>a</sup>Values are percentages of scores assigned within either temperature abused (T) or nonabused (N) product.

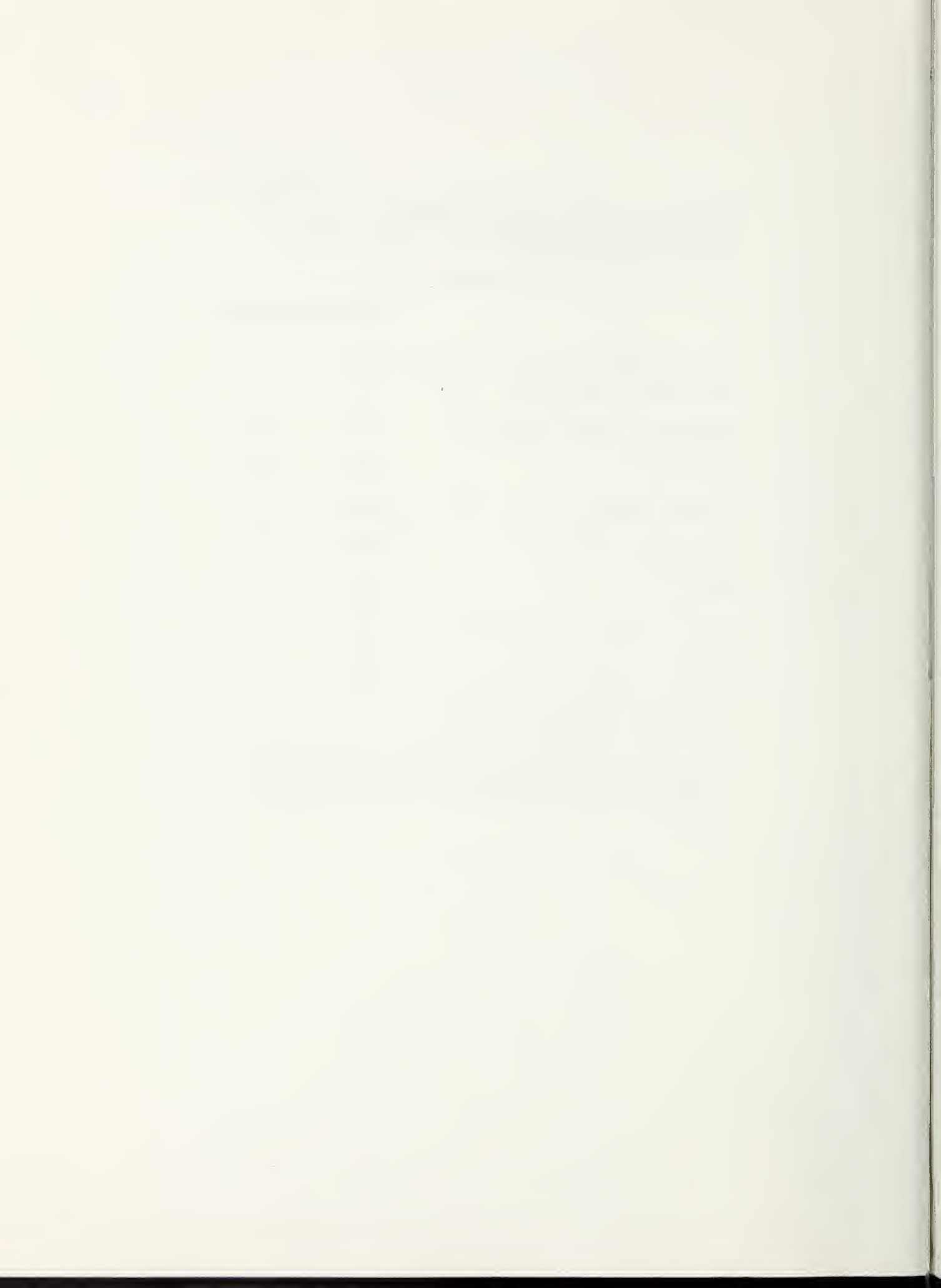




Table 4. Incidence of dark red color in frozen beef roasts throughout storage and according to freezing rate and final storage temperature<sup>a</sup>

Freezing Rate, hrs to 0°F	Final Storage Temperature, °F	Evaluation Time				
		Before freezing	Immediately after freezing, 1 day	6 mo	9 mo	12 mo
24	--	3.25	27.35	24.39	22.64	23.53
	-10			24.10	22.22	25.53
	+20			23.68	24.62	24.74
48	--	3.36	32.39	22.39	18.52	20.78
	-10			19.19	22.22	21.54
	+20			20.25	22.64	25.49
72	--	8.26	24.59	23.44	21.62	22.95
	-10			22.06	20.00	21.54
	+20			22.64	24.14	23.01
96	--	10.48	27.01	28.07	20.85	23.64
	-10			24.19	21.51	23.64
	+20			27.78	21.05	23.93

<sup>a</sup>Values are percent occurrence of dark red color among all colors within a storage time-freezing rate-final storage temperature combination.

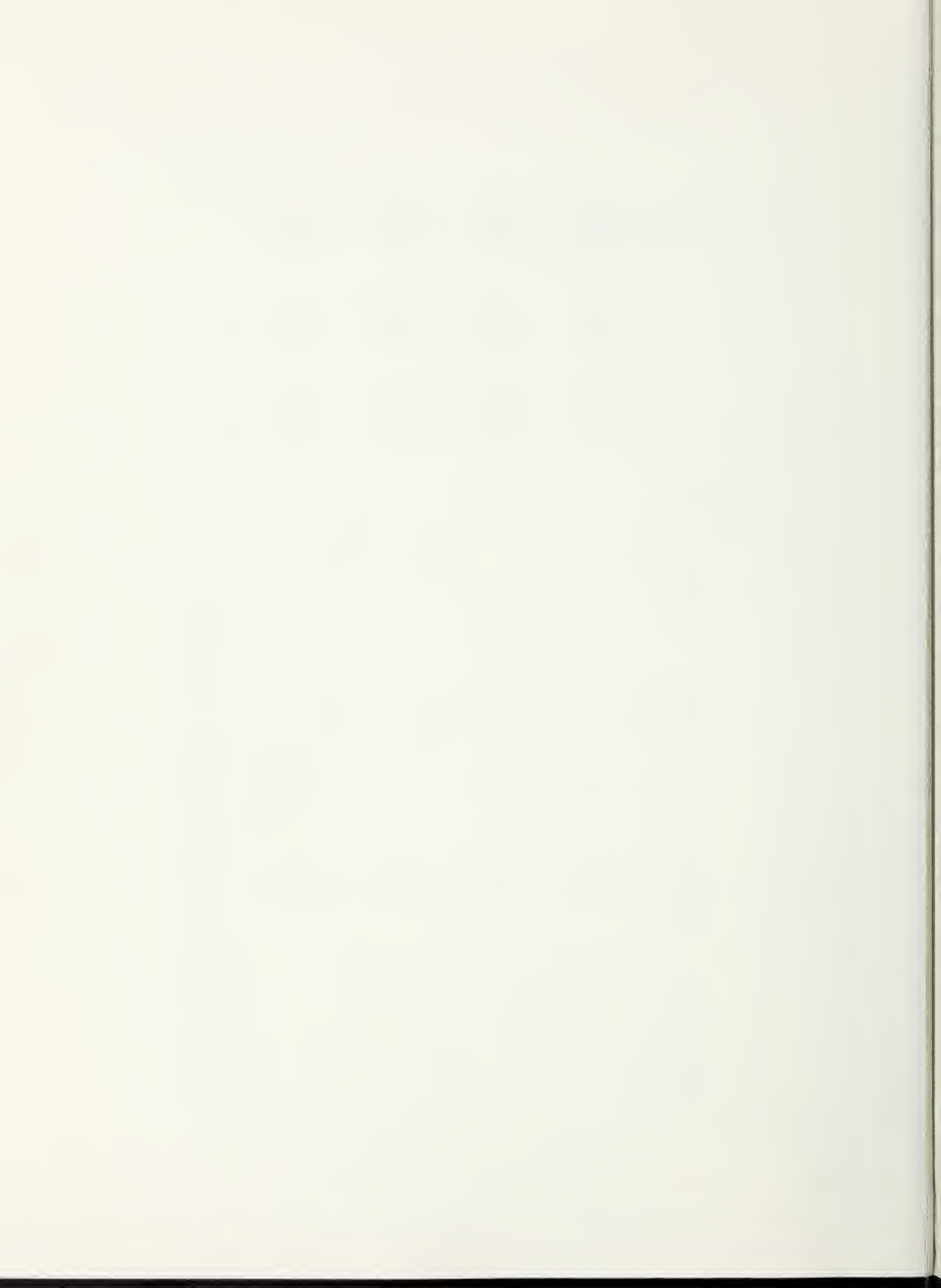


Table 5. Incidence of blackish purple color in frozen beef roasts throughout storage and according to freezing rate and final storage temperature<sup>a</sup>

Freezing Rate, hrs to 0°F	Final Storage Temperature, °F	Evaluation time				
		Before freezing	Immediately after freezing, 1 day	6 mo	9 mo	12 mo
24	--	0.00	18.80			
	-10			14.03	11.32	5.88
	0			16.87	9.72	8.51
	+20			23.68	15.38	8.25
48	--	0.84	19.72			
	-10			16.87	18.52	14.29
	0			18.18	11.11	10.77
	+20			20.25	16.98	13.73
72	--	0.00	15.57			
	-10			17.19	18.92	4.92
	0			17.65	15.71	1.54
	+20			22.64	22.41	6.19
96	--	4.03	18.98			
	-10			15.79	16.67	10.91
	0			24.19	9.68	14.55
	+20			29.63	21.05	8.55

a values are percent occurrence of blackish purple color among all colors within a storage time-freezing rate-final storage temperature combination.



Color scores on thawed roasts at six months, while statistically different, followed no apparent trend respective to freezing rate (Table 6). At twelve months, thawed roasts stored at +20°F displayed less very light cherry red and more dark red and very dark red (Table 7). While differences were noted respective to rate and final storage temperature, they followed no consistent trend. Following twelve months storage, thawed and temperature abused roasts were scored as being lighter in color than nonabused roasts (Table 8).

As with other pigments, moderately dark red was quite prevalent just before and after freezing (Table 9). Following twelve months of storage, this color was found more on the surface of roasts stored at +20°F than at 0 and -10°F.

Very dark red increased in frequency immediately following freezing for the faster rates of freezing and decreased for the slower rates of freezing (Table 10). Following twelve months of storage, roasts stored at +20°F had greater frequency of this pigment.

Table 11 provides general linear means and standard deviations for surface discoloration scores on frozen roasts throughout storage and according to final storage temperature and freezing rate. As can be noted, both temperature and nontemperature abused product was evaluated after twelve months storage.

Freezing in itself produced a considerable increase in surface discoloration (Table 12). Also, there was more discoloration after six, nine and twelve months compared to immediately following freezing. Comparisons of immediately following freezing with initial and final storage temperature combinations for surface discoloration on frozen roasts is presented in Table 13. One of the initial-final temperature



Table 6. Color scores assigned to thawed beef roasts according to freezing rate following six months storage<sup>a</sup>

Color	Freezing rate, hours to 0°F			
	24	48	72	96
Light grayish red	0.00	0.00	.38	0.00
Very light cherry red	3.02	9.09	12.41	11.85
Moderately light cherry red	9.05	14.97	9.02	4.27
Cherry red	8.62	3.21	3.38	3.79
Slightly dark red	22.41	21.39	20.68	15.17
Moderately dark red	18.10	18.72	15.04	18.01
Dark red	24.14	20.86	23.68	25.59
Very dark red	12.93	10.70	11.28	18.96
Blackish purple	1.72	1.07	4.14	2.37

Chi-square = 56.07;  $P < .0002$

<sup>a</sup>Values are percentages of scores assigned within rate of freezing.





Table 7. Color scores assigned to thawed beef roasts according to freezing rate and final storage temperature following twelve months storage<sup>a</sup>

Rate, hr to 0°F	Final storage temperature, °F	Color							
		Light grayish red	Very light cherry red	Moderately light cherry red	Cherry red	Slightly dark red	Moderately dark red	Dark red	Very dark red
24	-10	1.75	17.54	19.30	3.51	19.30	21.05	14.04	3.51
	0	0.00	12.70	17.46	0.00	20.63	19.05	17.46	9.52
	+20	0.00	2.42	13.71	5.65	23.39	20.16	21.77	12.10
48	-10	2.20	19.78	16.48	3.30	18.68	19.78	18.68	1.10
	0	0.00	17.91	22.39	2.99	25.37	19.40	10.45	1.49
	+20	0.00	3.50	16.08	6.29	22.38	19.58	20.98	10.49
72	-10	1.35	14.86	10.81	8.11	20.27	18.92	20.27	5.41
	0	1.45	13.04	21.74	8.70	20.29	18.84	15.94	0.00
	+20	0.00	7.59	16.55	4.83	20.00	21.38	21.38	7.59
96	-10	1.56	21.88	18.75	1.56	23.44	18.75	14.06	0.00
	0	1.54	12.31	13.85	6.15	24.62	16.92	21.54	1.54
	+20	0.00	3.94	13.39	4.72	24.41	22.05	22.83	7.87

Chi-square = 133.58,  $P < .0118$

<sup>a</sup>Values are percentages of scores assigned within a rate - final storage temperature combination.



Table 8. Color scores assigned to thawed beef roasts according to temperature abuse following twelve months storage<sup>a</sup>

Color	Temperature abuse	
	T	N
Light grayish red	.86	0.00
Very light cherry red	12.42	4.71
Moderately light cherry red	17.34	13.04
Cherry red	4.67	5.43
Slightly dark red	22.02	21.74
Moderately dark red	19.68	20.65
Dark red	18.08	22.46
Very dark red	4.31	11.23
Blackish purple	.49	.72

Chi-square = 35.70,  $P < .0001$

<sup>a</sup>Values are percentages of scores assigned within either temperature abused (T) or nonabused (N) product.

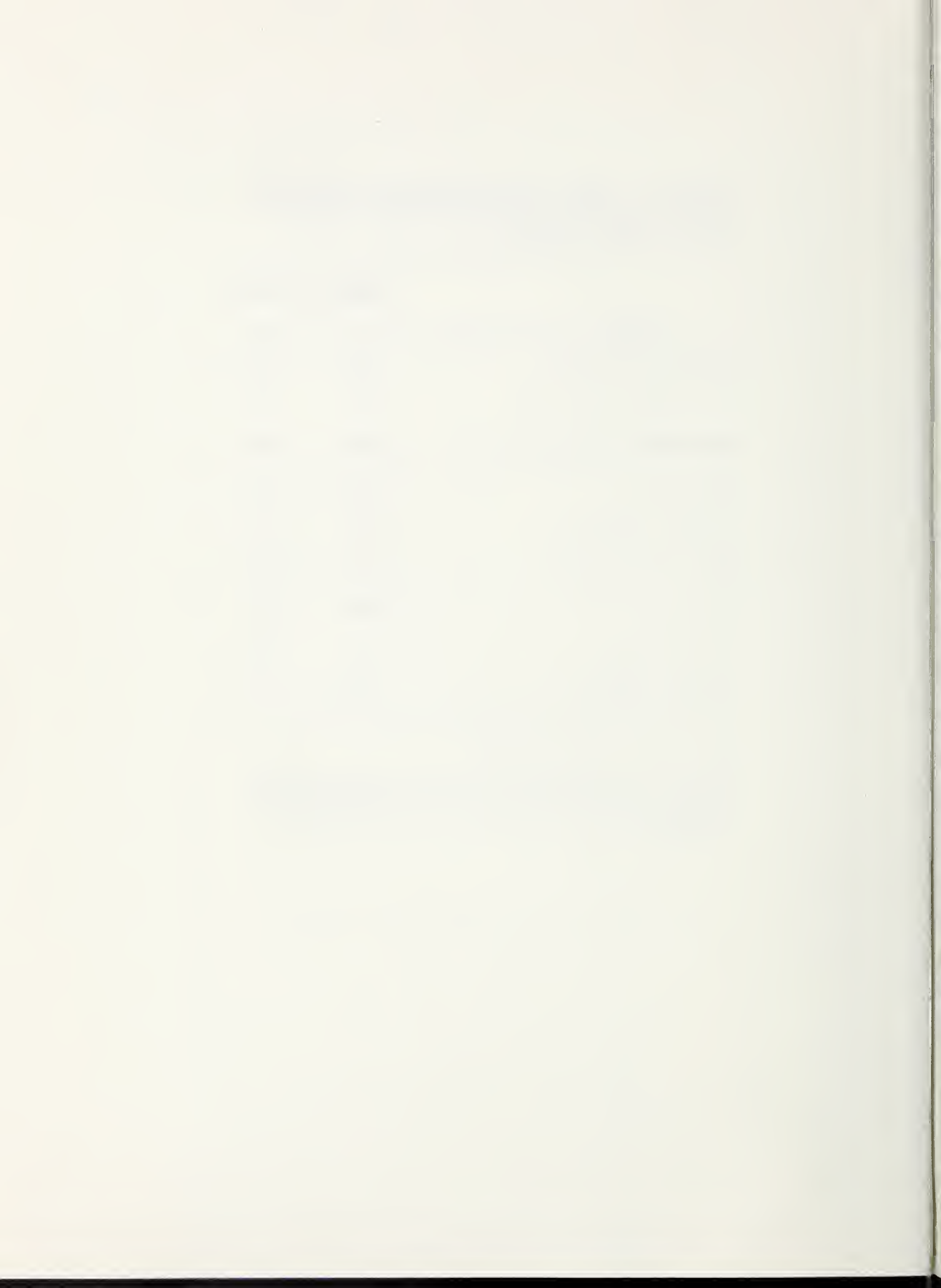


Table 9. Incidence of moderately light cherry red color in thawed beef roasts throughout storage and according to freezing rate and final storage temperature<sup>a</sup>

Freezing Rate, hrs to 0°F	Final Storage Temperature, °F	Evaluation Time				
		Before freezing	Immediately after freezing, 1 day	6 mo	9 mo	12 mo
24	--	23.58	12.99			
	-10			10.84	11.93	19.30
	0			6.67	17.07	17.46
	+20			9.46	10.96	13.71
48	--	22.69	13.13			
	-10			16.95	12.99	16.48
	0			13.11	15.00	22.39
	+20			14.93	16.87	16.08
72	--	19.83	19.41			
	-10			8.64	7.46	10.81
	0			10.89	10.00	21.74
	+20			7.14	15.07	16.55
96	--	20.16	13.61			
	-10			5.97	14.44	18.75
	0			4.29	13.64	13.85
	+20			2.70	14.77	13.39

<sup>a</sup>Values are percent occurrence of moderately light cherry red color among all colors within a storage time-freezing rate-final storage temperature combination.

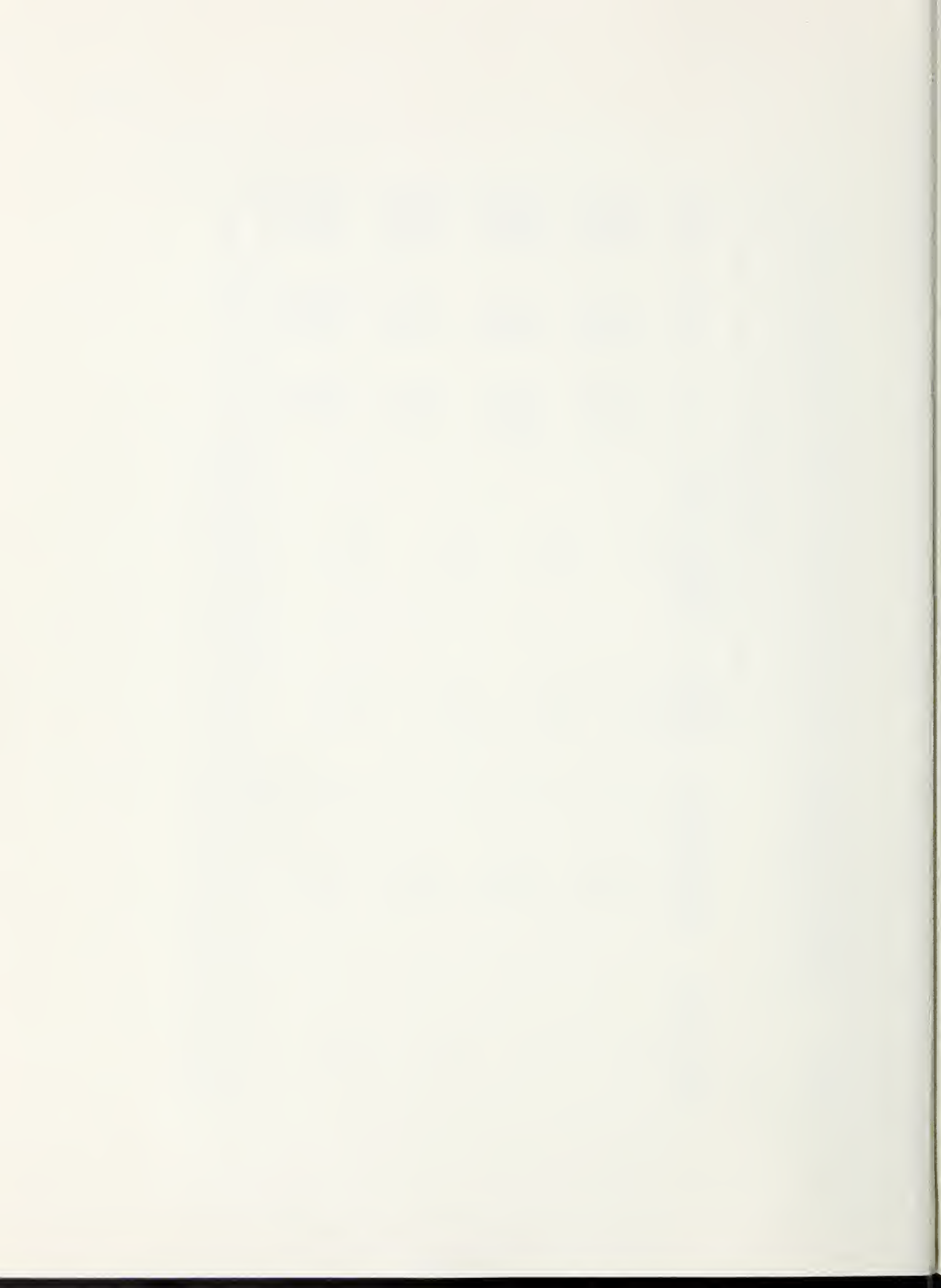


Table 10. Incidence of dark red color in thawed beef roasts throughout storage and according to freezing rate and final storage temperature<sup>a</sup>

Freezing Rate, hrs to 0°F	Final Storage Temperature, °F	Evaluation Time				
		Before freezing	Immediately after freezing, 1 day	6 mo	9 mo	12 mo
24	--	3.25	17.53			
	-10			24.10	19.27	14.04
	0			25.33	18.29	17.46
48	+20	3.36	16.16	22.97	23.29	21.77
	--					
	-10			20.34	16.88	18.68
72	0	8.26	17.06	19.67	16.25	10.45
	+20			22.39	18.07	20.98
	--					
96	-10	10.48	17.16	24.69	22.39	20.27
	0			22.77	20.00	15.94
	+20			23.61	21.92	21.38
	--					
	-10			26.87	17.78	14.06
	0			25.74	17.05	21.54
	+20			24.32	21.59	22.83

<sup>a</sup>Values are percent occurrence of dark red color in beef roasts throughout storage and according to freezing rate and final storage temperature.

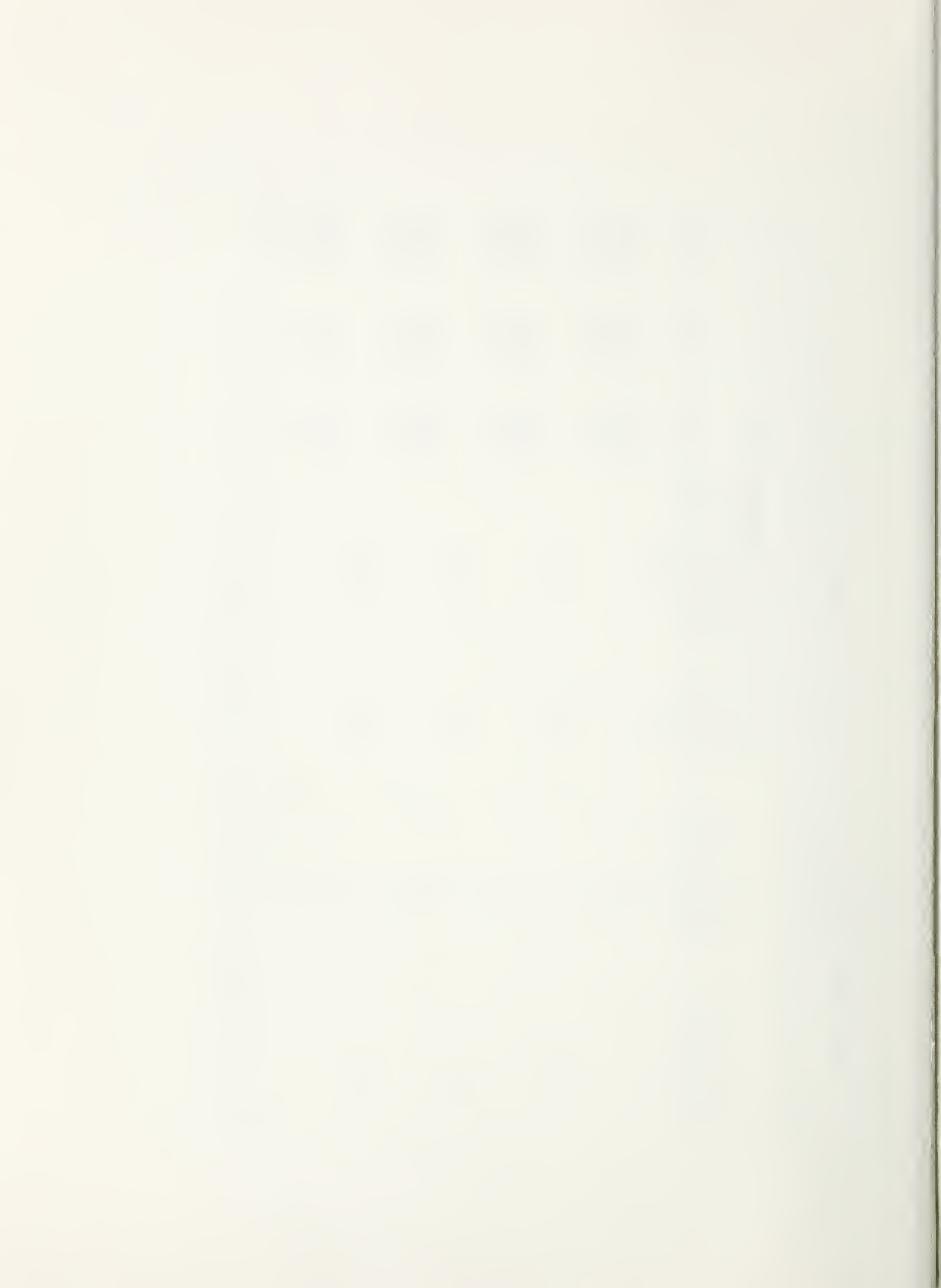




Table 11. General table illustrating sensory scores for surface discoloration on frozen beef roasts throughout storage and according to final storage temperature and rate of freezing - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		5.22 ± 1.07	6.00 ± .55	5.62 ± .94	5.71 ± .69
Immediately after freezing, 1 day		3.91 ± .93	3.79 ± .72	3.31 ± 1.12	3.20 ± .97
6 months	-10T	2.70 ± .86	2.65 ± .49	2.31 ± .48	2.56 ± .63
	0T	2.55 ± .83	2.85 ± .67	2.37 ± .72	2.19 ± .54
	20T	1.85 ± .74	1.55 ± .60	1.56 ± .51	1.69 ± .70
9 months	-10T	2.50 ± .80	2.67 ± .65	2.25 ± .45	2.40 ± .60
	0T	2.62 ± 1.03	3.00 ± .60	2.52 ± .94	2.45 ± .51
	20T	2.44 ± .83	1.83 ± .58	1.69 ± .61	2.25 ± .45
12 months	-10T	2.50 ± .80	3.31 ± .60	2.71 ± .61	2.27 ± .48
	0T	2.42 ± .51	3.37 ± .50	2.19 ± .43	2.14 ± .38
	20T	1.75 ± .75	1.73 ± .47	1.77 ± .58	1.67 ± .50
	20N	1.92 ± .51	2.25 ± .45	1.67 ± .49	2.27 ± .58

<sup>a</sup>mean ± S.E. T = temperature abused; N = not temperature abused.

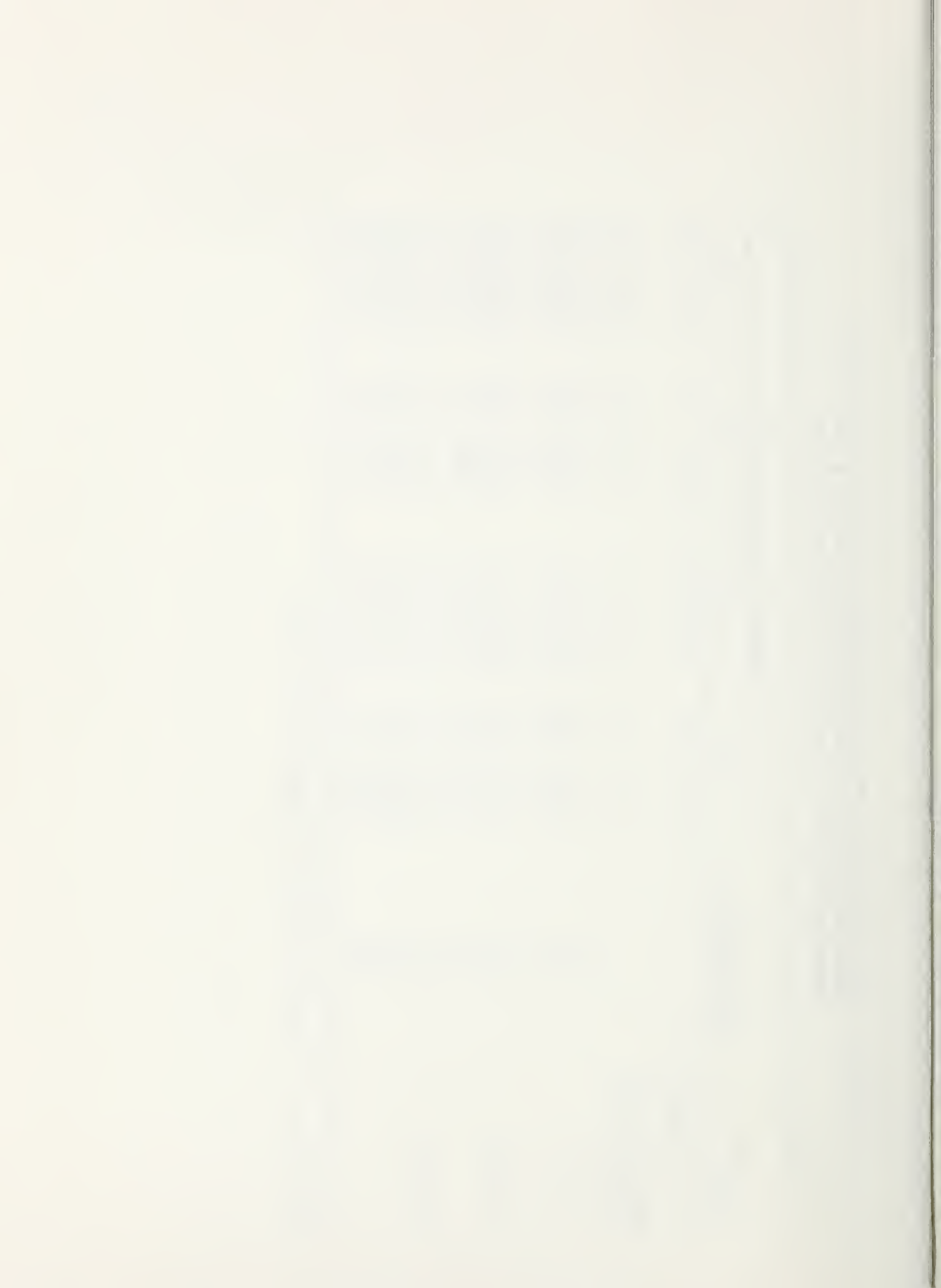


Table 12 . Effect of various storage time comparisons on sensory scores for surface discoloration on frozen beef roasts

Evaluation times	
Immediately before freezing	Immediately following freezing, 1 day
5.64 $\pm$ .14a	3.55 $\pm$ .14b
Immediately following freezing, 1 day	6 months
3.57 $\pm$ .22a	2.24 $\pm$ .22b
Immediately following freezing, 1 day	9 months
3.57 $\pm$ .22a	2.38 $\pm$ .22b
Immediately following freezing, 1 day <sup>c</sup>	12 months <sup>c</sup>
3.69 $\pm$ .22a	2.32 $\pm$ .22b
Immediately following freezing, 1 day	12 months <sup>d</sup>
3.57 $\pm$ .13a	1.88 $\pm$ .13b

ab Means on the same line with different letters are different. Mean  $\pm$  S.E.

<sup>c</sup>Includes just temperature abused product.

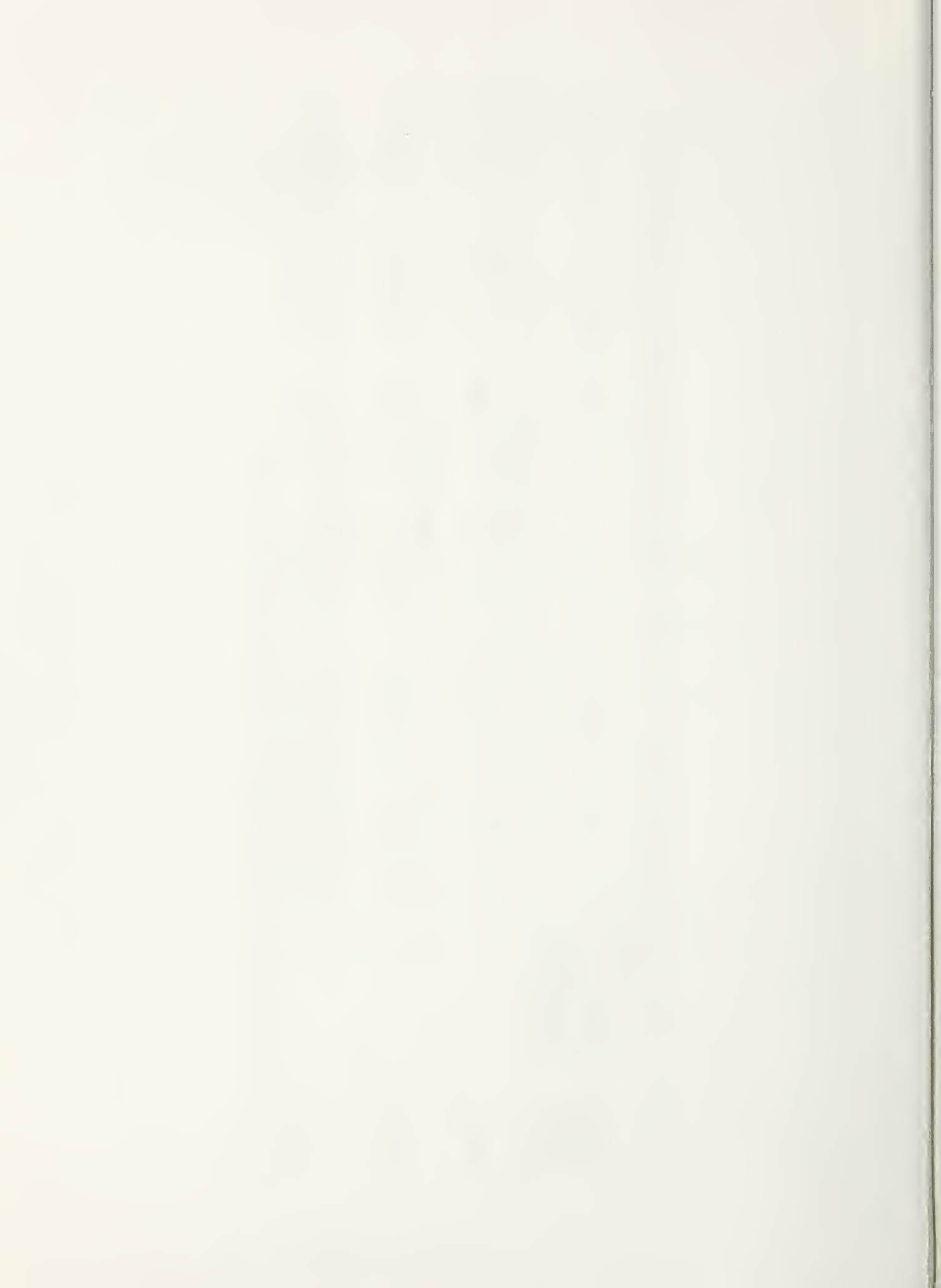
<sup>d</sup>Includes just +20°F final storage temperature product.



Table 13 . Effect of various storage time comparisons on sensory scores for surface discoloration on frozen beef roasts

Immediately following freezing, 1 day	Initial storage temperature, °F =			Final storage temperature, °F =		
	-10	0	20	-10	0	20
3.57 ± .15a	6 months storage					
	2.4 ± .26bcd	2.08 ± .26bcd	1.51 ± .26d	2.71 ± .26abc	2.9 ± .26ab	1.81 ± .26cd
	9 months storage					
3.57 ± .16a	2.2 ± .27b	2.33 ± .27b	1.99 ± .27b	2.71 ± .27ab	2.96 ± .27ab	2.11 ± .27b
	12 months storage					
	2.52 ± .28bc	2.50 ± .28bc	1.74 ± .28c	2.9 ± .28ab	2.59 ± .28bc	1.75 ± .28c

abc Means on the same line with the same letters are not different ( $P>.05$ ). Mean ± S.E.



combinations (0°F initial, -10°F final) did not increase in surface discoloration over that found immediately following freezing at either six, nine or twelve months. At six and nine months, 0°F initial and 0°F final storage temperatures also did not produce a significant ( $P < .05$ ) increase in surface discoloration over that scored immediately following freezing. For product initially stored at 0°F, that held finally at +20°F had more surface discoloration than roasts stored at -10°F at both six and twelve months, but not at nine months.

The effects of final storage temperature itself on surface discoloration in roasts is given in Table 14. Following either six, nine or twelve months, +20°F product had more discoloration than product held at -10 and 0°F temperatures. An interaction of storage time (six, nine months) with final storage temperature is shown in Table 15. Roasts stored at +20°F were rated as more discolored than those held at -10 and 0°F for both storage periods. In addition, roasts stored at six months at +20°F displayed more discoloration than roasts stored for nine months at +20°F. A similar type interaction comparison for nine and twelve months (Table 16) showed slightly different results. Product stored at +20°F for six months did not differ in surface discoloration from that held at -10°F for six months or stored at +20°F for twelve months.

A significant ( $P < .05$ ) interaction of storage time (nine, twelve months) and freezing rate was detected for surface discoloration on frozen roasts (Table 17). Freezing rate did not affect scores within nine months stored product, while at twelve months, roasts frozen to 0°F in 48 hr displayed less discoloration than the other three frozen rates. Comparison of storage times within rates failed to produce any significant differences. A significant freezing rate by initial storage temperature

The first part of the paper discusses the importance of the  
 research and the objectives of the study. It also outlines the  
 methodology used in the study and the data sources. The second  
 part of the paper presents the results of the study and discusses  
 the implications of the findings. The third part of the paper  
 concludes the study and provides recommendations for future  
 research.



Table 14 . Effect of final storage temperature on sensory scores for surface discoloration on frozen beef roasts following either six, nine or twelve months storage

Evaluation time, months	Final storage temperature, °F		
	-10	0	20
6	2.56 $\pm$ .13a	2.49 $\pm$ .13a	1.66 $\pm$ .13b
9	2.45 $\pm$ .14ab	2.65 $\pm$ .14a	2.05 $\pm$ .14b
12	2.70 $\pm$ .13a	2.53 $\pm$ .13a	1.73 $\pm$ .13b

ab Means on the same line with the same letters are not different ( $P>.05$ ). Mean  $\pm$  S.E.



Table 15 . Interaction of storage time (six, nine months) and final storage temperature on sensory scores for surface discoloration on frozen beef roasts

Evaluation time, months	Final storage temperature, °F		
	-10	0	20
6	2.56 $\pm$ .078a	2.49 $\pm$ .078a	1.66 $\pm$ .078c
9	2.45 $\pm$ .078a	2.65 $\pm$ .078a	2.05 $\pm$ .078b

ab Any mean comparisons with the same letter are not different ( $P > .05$ ).  
Mean  $\pm$  S.E.



Table 16 . Interaction effect of storage time (nine, twelve months) and final storage temperature on sensory scores for surface discoloration on frozen beef roasts

Evaluation Time, months	Final Storage Temperature, °F		
	-10	0	+20
9	2.45 $\pm$ .10ab	2.65 $\pm$ .10a	2.05 $\pm$ .10bc
12	2.70 $\pm$ .10a	2.53 $\pm$ .10a	1.73 $\pm$ .10c

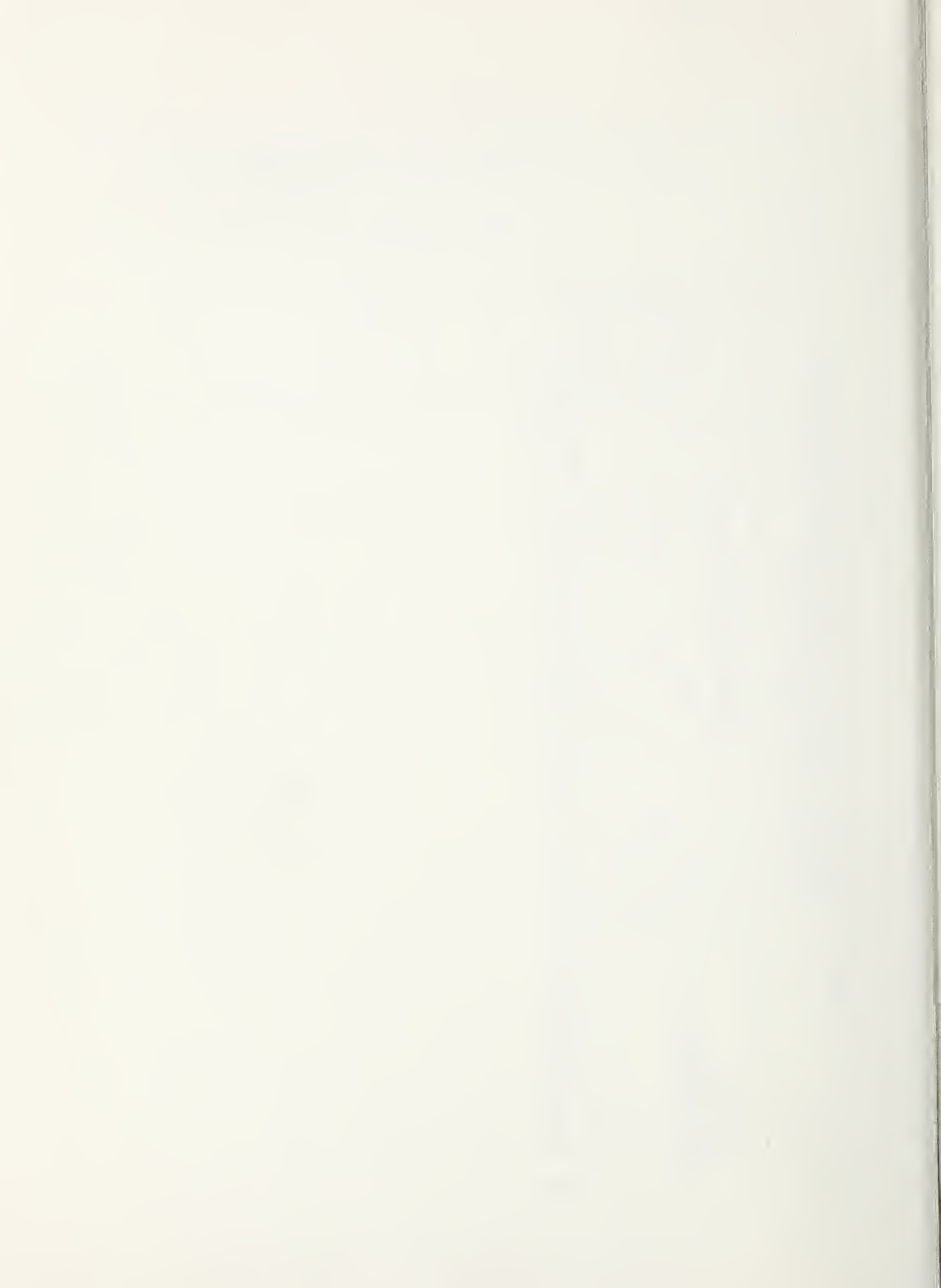
abc Any mean comparison with the same letter is not different ( $P>.05$ ). Mean  $\pm$  S.E.



Table 17 . Interaction effect of storage time (nine, twelve months) and rate of freezing on sensory scores for surface discoloration on frozen beef roasts

Evaluation time, months	Freezing rate, hours to °F			
	24	48	72	96
9	2.52 ± .11ab	2.5 ± .11ab	2.15 ± .11b	2.37 ± .11ab
12	2.22 ± .11b	2.81 ± .11a	2.22 ± .11b	2.03 ± .11b

ab Any mean comparison with the same letters is not different ( $P > .05$ ). Mean ± S.E.





interaction was noted for surface discoloration on frozen roasts after twelve months storage (Table 18). However, this effect was detected only by analysis of variance and not by HSD. Also, after twelve months storage, nontemperature abused product showed more evidence of discoloration than temperature abused product (Table 19).

The general table illustrating overall linear means and standard deviations for surface discoloration on thawed roasts is presented in Table 20. The trend was for more discoloration to be noted with the +20°F storage temperature.

Comparisons of the significant ( $P < .05$ ) differences of storage times compared with immediately following freezing for discoloration on thawed roasts are shown in Table 21. There was also again a sizeable increase in surface discoloration solely as a function of just freezing. After all storage periods, roasts were more discolored than just after freezing.

Product frozen to 0°F in 48 hr had less discoloration than roasts frozen to 72 or 96 hr immediately following freezing (Table 22). This difference was true at six months of storage but only for the 0°F in 48 hr vs 0°F in 96 hr comparison. This difference between 0°F in 48 hr and 0°F in 96 hr was not found after nine months of storage (Table 23).

However, at nine months of storage, roasts stored at 0°F displayed less discoloration than roasts held at either -10°F or +20°F (Table 24). Final storage temperature was also involved in an interaction with nine and twelve month storage time (Table 25). After nine months storage, roasts stored at 0°F had less discoloration than +20°F stored roasts. This was true after twelve months storage, but discoloration on thawed roasts stored at -10°F was also less than +20°F stored roasts. A comparison of values obtained immediately following freezing with various initial-final storage

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Table 18. Interaction effect of initial storage temperature and rate of freezing on sensory scores for surface discoloration on frozen beef roasts following twelve months of storage<sup>a</sup>

Initial storage temperature, °F	Freezing rate, hours to °F		
	24	48	72
-10	2.17 ± .17	1.98 ± .17	1.6 ± .17
0	1.5 ± .17	2.0 ± .17	1.83 ± .17
			2.15 ± .17

<sup>a</sup>Interaction effect significant ( $P < .05$ ) by analysis of variance but not by HSD. Mean ± S.E.. Includes just +20°F final storage product and both temperature abused and nonabused product.

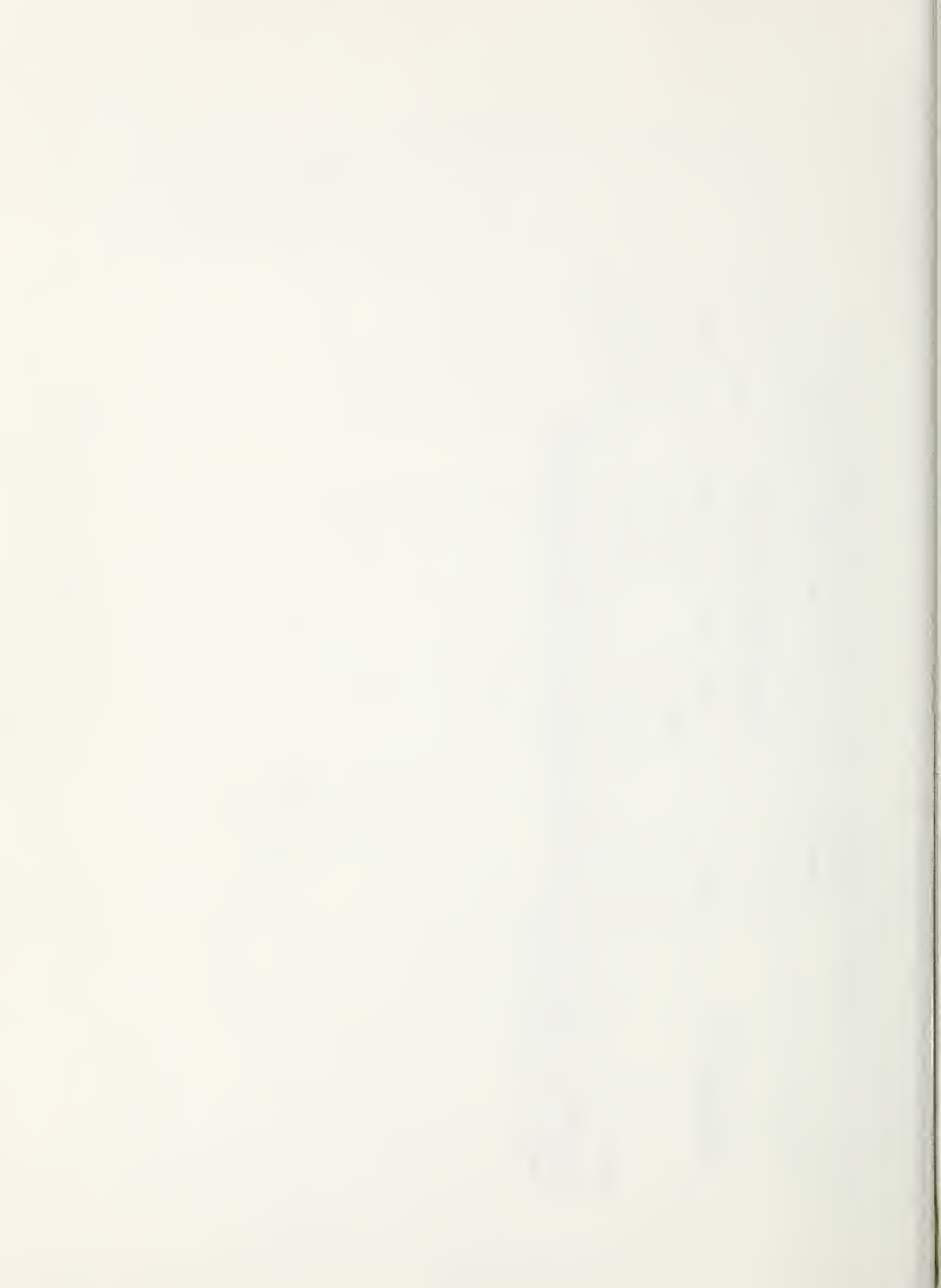


Table 19. Effect of temperature abuse on sensory scores for surface discoloration on frozen beef roasts following twelve months storage

Temperature Abuse	
T	N
1.73 $\pm$ .087b	2.03 $\pm$ .087a

ab Difference between means significant ( $P < .05$ ).  
Mean  $\pm$  S.E.



Table 20. General table illustrating the sensory scores for surface discoloration on thawed beef roasts throughout storage and according to final storage temperature and rate of freezing - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		5.22 ± 1.07	6.00 ± .55	5.62 ± .94	5.71 ± .69
Immediately after freezing, 1 day		3.52 ± .96	4.12 ± .61	2.97 ± .80	2.92 ± .83
6 months	-10T	2.55 ± .69	2.81 ± .54	2.65 ± .49	2.42 ± .62
	0T	2.50 ± .51	2.94 ± .44	2.65 ± .61	1.96 ± .54
	20T	2.00 ± .65	2.44 ± .51	2.50 ± .51	2.20 ± .43
9 months	-10T	2.17 ± .64	2.21 ± .43	2.28 ± .51	2.35 ± .59
	0T	2.79 ± .80	2.66 ± .59	2.39 ± .50	2.25 ± .44
	20T	2.17 ± .51	2.00 ± .72	2.00 ± .34	2.3 ± .47
12 months	-10T	2.52 ± .52	2.85 ± .37	2.75 ± .45	2.37 ± .62
	0T	2.67 ± .50	3.12 ± .62	2.56 ± .51	2.75 ± .45
	20T	1.98 ± .39	2.12 ± .32	1.88 ± .50	2.12 ± .62
	20N	2.0 ± .36	2.12 ± .62	2.19 ± .54	1.81 ± .54

<sup>a</sup>Mean ± S.E.; T = Temperature abused; N = Not temperature abused.

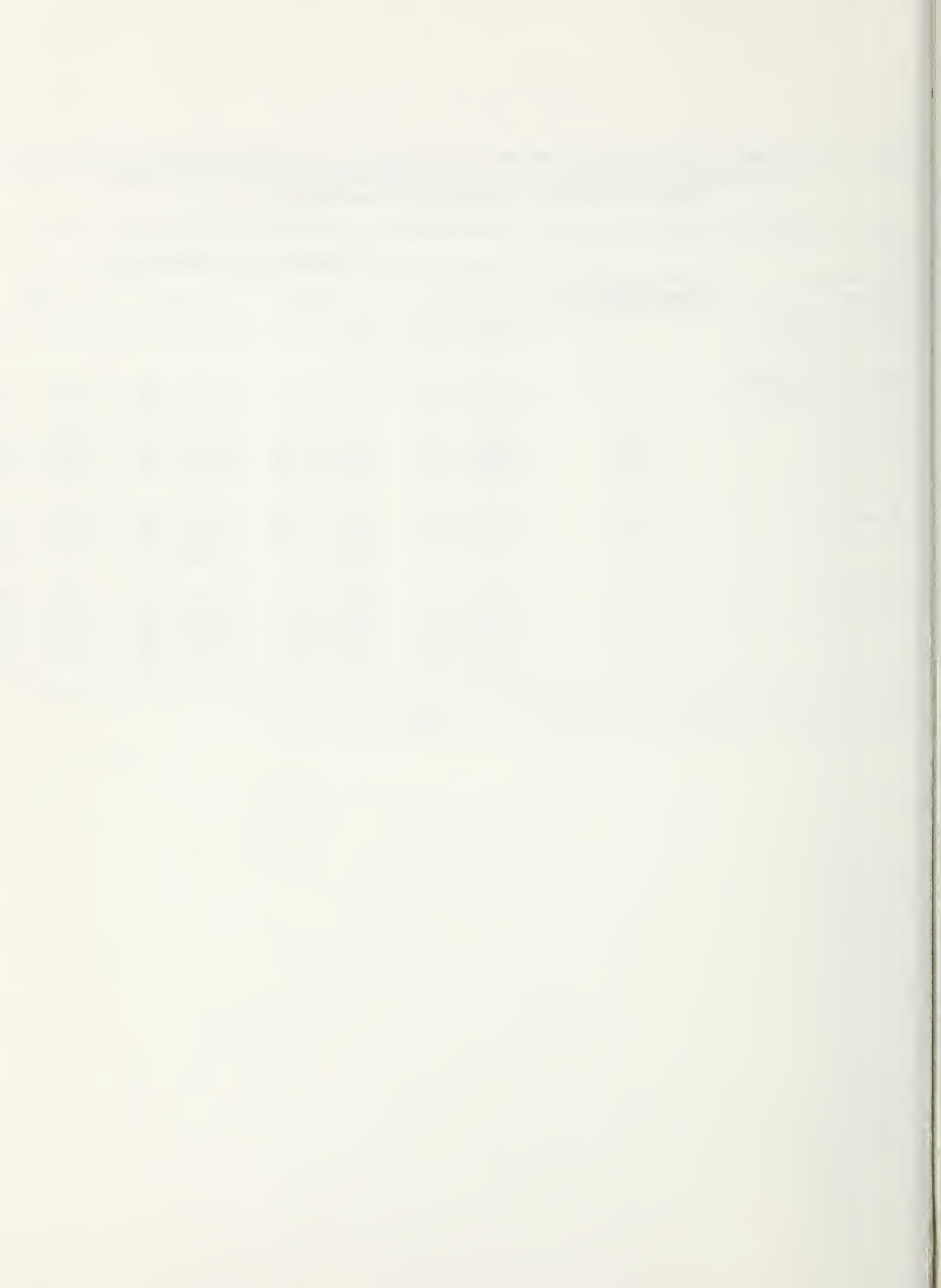




Table 21 . Effect of various storage time comparisons on sensory scores for surface discoloration on thawed beef roasts

Evaluation times	
Before freezing	Immediately following freezing, 1 day
5.64 $\pm$ .11a	3.37 $\pm$ .14b
Immediately following freezing, 1 day	6 months
3.49 $\pm$ .19a	2.47 $\pm$ .19b
Immediately following freezing, 1 day	9 months
3.49 $\pm$ .19a	2.30 $\pm$ .19b
Immediately following freezing, 1 day	12 months <sup>c</sup>
3.43 $\pm$ .19a	2.47 $\pm$ .19b
Immediately following freezing, 1 day	12 months <sup>d</sup>
3.39 $\pm$ .14a	2.03 $\pm$ .14b

ab Means on the same line with different letters are different ( $P < .05$ );  
Mean  $\pm$  S.E.

<sup>c</sup>Includes only temperature abused product.

<sup>d</sup>Includes only +20°F stored product.

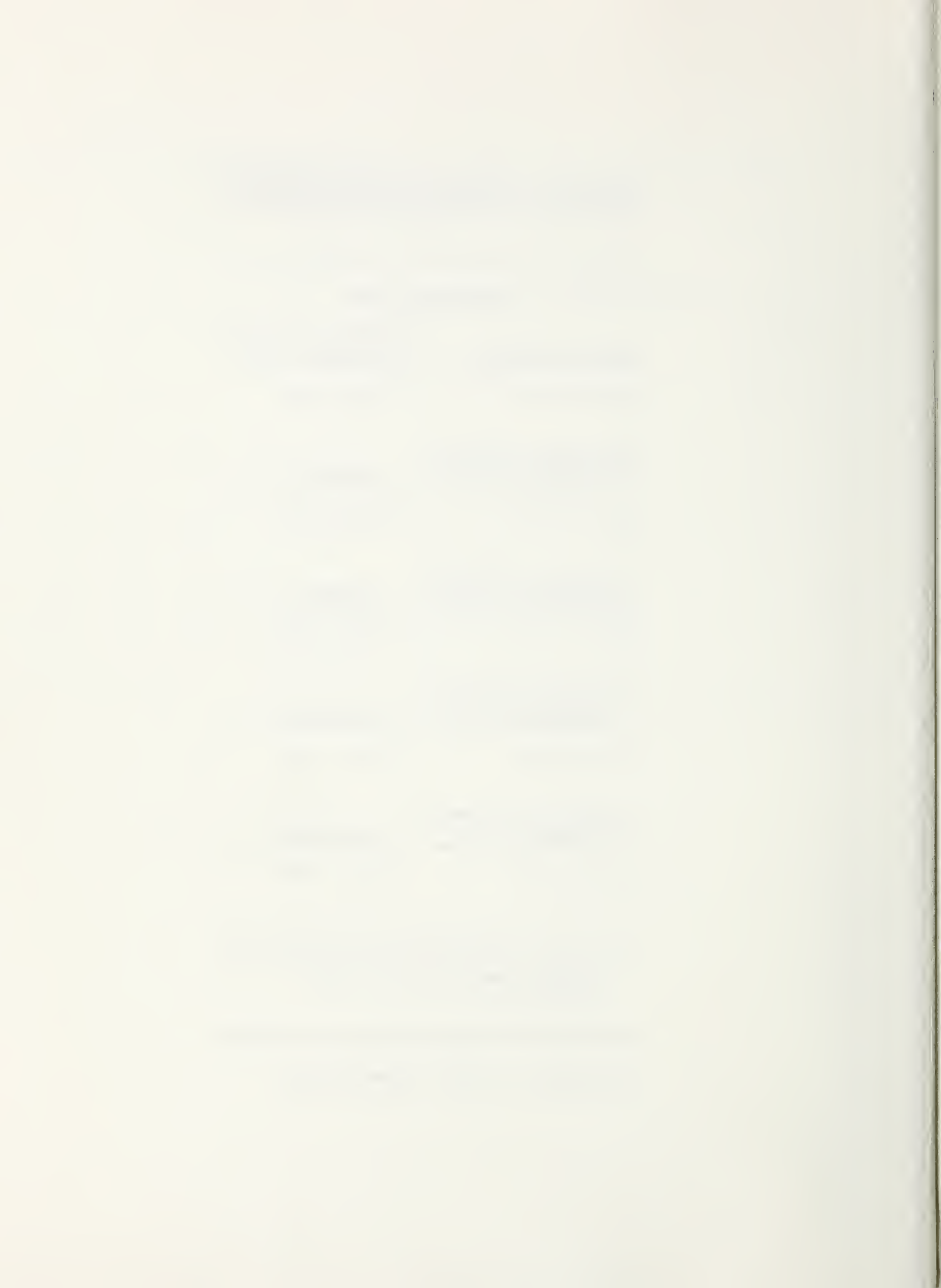


Table 22 . Effect of various storage time comparisons on sensory scores for surface discoloration on thawed beef roasts

Evaluation time	Freezing rate, hours to 0°F			
	24	48	72	96
Immediately following freezing, 1 day	3.52 $\pm$ .23ab	4.12 $\pm$ .33a	2.97 $\pm$ .23b	2.92 $\pm$ .23b
6 months	2.34 $\pm$ .11ab	2.73 $\pm$ .11a	2.6 $\pm$ .11ab	2.20 $\pm$ .11b

ab Means on the same line with the same letters are not different ( $P > .05$ );  
Mean  $\pm$  S.E.

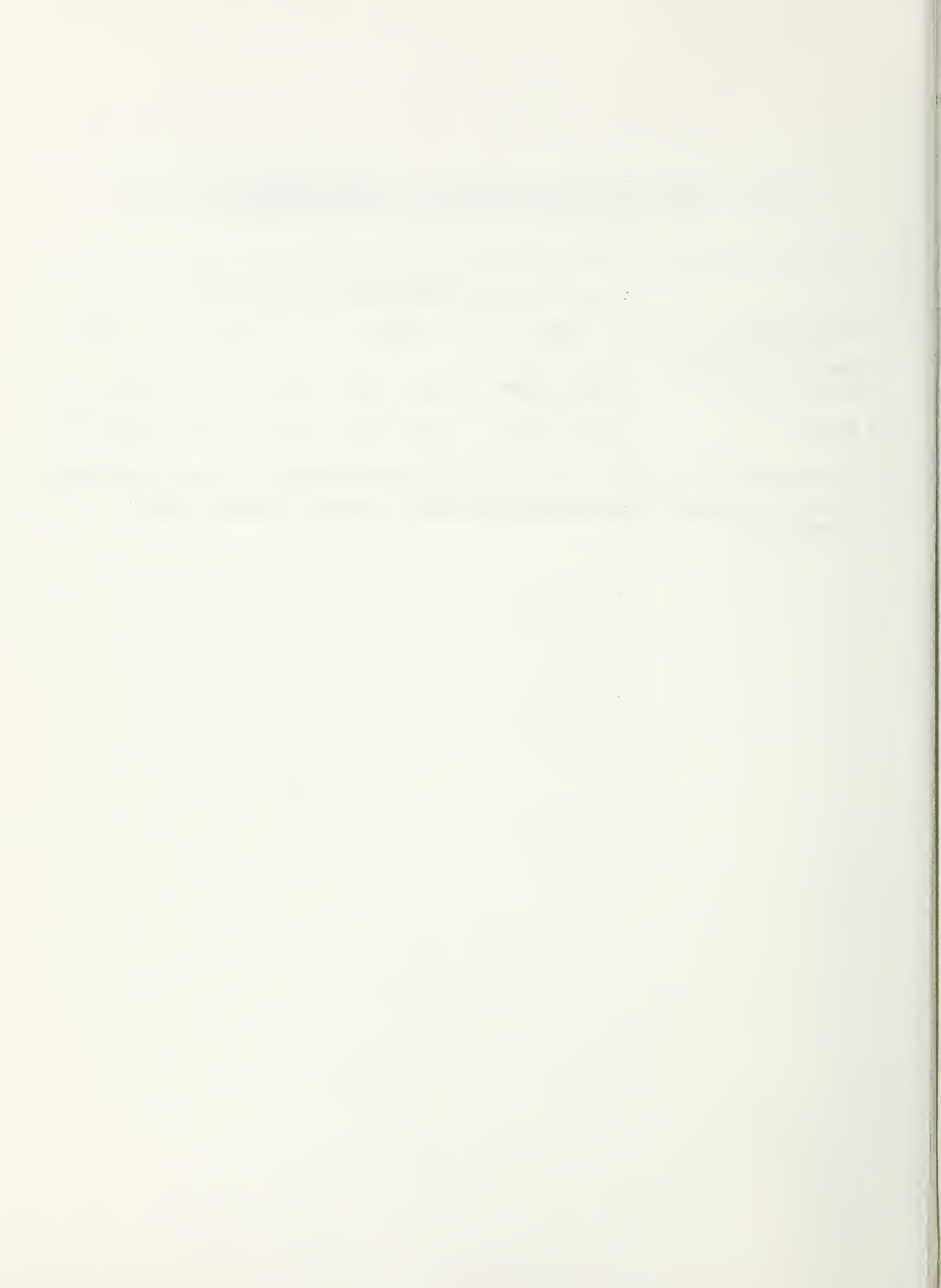


Table 23 . Interaction effect of storage time (six, nine months) and rate of freezing on sensory scores for surface discoloration on thawed beef roasts

Evaluation time, months	Freezing rate, hours to 0°F			
	24	48	72	96
6	2.35 $\pm$ .11ab	2.73 $\pm$ .11a	2.6 $\pm$ .11ab	2.2 $\pm$ .11b
9	2.37 $\pm$ .11ab	2.29 $\pm$ .11ab	2.22 $\pm$ .11b	2.3 $\pm$ .11ab

ab Any mean comparison with the same letters is not different ( $P > .05$ ); Mean  $\pm$  S.E.

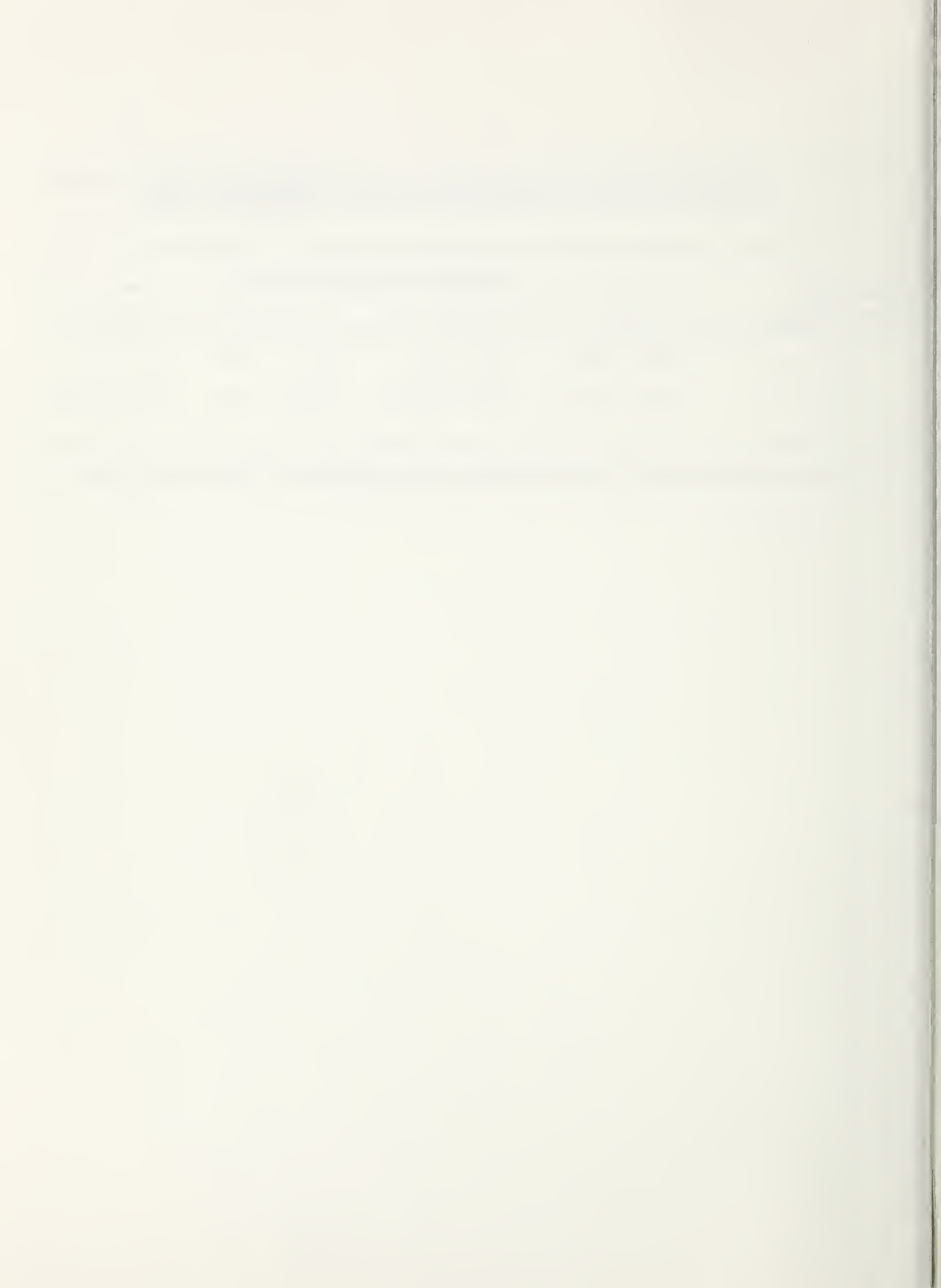


Table 24 . Effect of final storage temperature on sensory scores for surface discoloration on thawed beef roasts following 9 months of storage

Final storage temperature, °F		
-10	0	20
2.25 ± .072b	2.52 ± .072a	2.12 ± .072b

ab Means on the same line with different letters are different ( $P < .05$ ); Mean ± S.E.

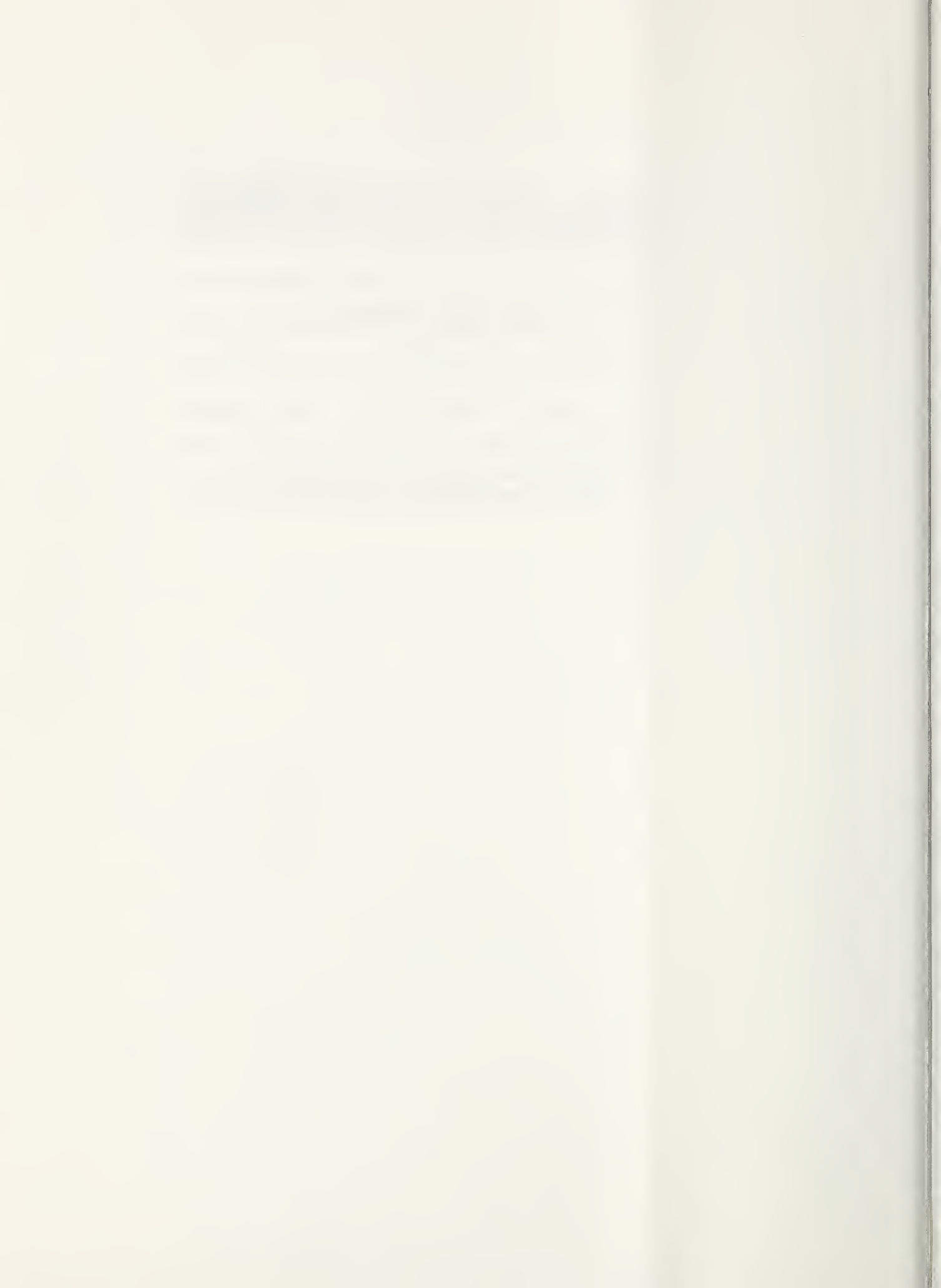




Table 25. Interaction effect of storage time (nine, twelve months) and final storage temperature on sensory scores for surface discoloration on thawed beef roasts

Evaluation time, months	Final storage temperature, °F		
	-10	0	20
9	2.25 ± .09bc	2.52 ± .09ab	2.12 ± .09c
12	2.62 ± .09ab	2.78 ± .09a	2.03 ± .09c

abc Any mean comparison with different letters is different ( $P < .05$ );  
Mean ± S.E.



temperature values at twelve months (Table 26) showed no difference between immediately following freezing and  $-10^{\circ}\text{F}$  initial and  $0^{\circ}\text{F}$  final storage temperature product.

A significant ( $P<.05$ ) interaction was also found for thawed roast discoloration according to initial storage temperature, final storage temperature and freezing rate (Table 27). Two major differences are responsible for this significant interaction--the less discoloration on roasts frozen to  $0^{\circ}\text{F}$  in 48, initially stored at  $0^{\circ}\text{F}$  and finally stored at  $0^{\circ}\text{F}$  vs roasts frozen and initially stored the same, but held at  $+20^{\circ}\text{F}$ . The other major difference was the reduced discoloration occurred in the  $0^{\circ}\text{F}$  in 72 hr rate where  $-10^{\circ}\text{F}$  initial and  $-10^{\circ}\text{F}$  final temperature stored product had less discoloration than  $0^{\circ}\text{F}$  initial and  $+20^{\circ}\text{F}$  final temperature stored product.

The general table showing linear means and standard deviations for percent freezer burn is provided in Table 28. More freezer burn appeared as storage time progressed, especially for roasts frozen  $^{\circ}\text{F}$  in 96 hr. Following both six and nine months of storage, roasts displayed more freezer burn than immediately following freezing (Table 29). However, twelve month stored roasts showed less freezer burn than nine-month stored roasts.

A significant ( $P<.05$ ) interaction (by analysis of variance, but not HSD) was noted for freezer burn on roasts at twelve months according to initial and final storage temperatures (Table 30). However, at twelve months, roasts frozen to  $0^{\circ}\text{F}$  in 24 hr showed less freezer burn than roasts frozen to  $0^{\circ}\text{F}$  in 96 hr (Table 31). Comparisons of immediately after freezing with initial-final temperature combinations at nine and twelve months are shown in Table 32. At nine months only, the  $0^{\circ}\text{F}$  initial and



Table 26. Effect of storage time (immediately following freezing, twelve months) on sensory scores for surface discoloration on thawed beef roasts

		12 months storage			
Immediately following freezing, 1 day	Initial Storage temperature, °F =	-10			
	Final Storage temperature, °F =	-10	20	-10	20
3.43 ± .14a		2.6 ± 1.5bc	2.84 ± .15ab	2.12 ± .15cd	2.56 ± .17bc
				2.67 ± .17bc	1.88 ± .17d

abcd Any mean comparison with different letters is different ( $P < .05$ ); Mean ± S.E.



Table 27. Interaction effect of initial storage temperature, final storage temperature and rate of freezing on sensory scores for surface discoloration on thawed beef roasts following twelve months storage

Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
-10	-10	2.37 + .19abcd	2.90 + .19abc	3.00 + .19ab	2.12 + .19bcd
	0	2.50 + .19abcd	3.50 + .19a	2.50 + .19abcd	2.87 + .19abcd
	20	2.12 + .19bcd	2.00 + .19bcd	2.00 + .19bcd	2.37 + .19abcd
0	-10	2.67 + .19abcd	2.80 + .19abcd	2.50 + .19abcd	2.62 + .19abcd
	0	2.83 + .19abcd	2.75 + .19abcd	2.62 + .19abcd	2.62 + .19abcd
	20	1.83 + .19cd	2.25 + .19bcd	1.75 + .19d	1.87 + .19cd

abcd Any mean comparison with the same letters is not different ( $P > .05$ ); Mean  $\pm$  S.E.

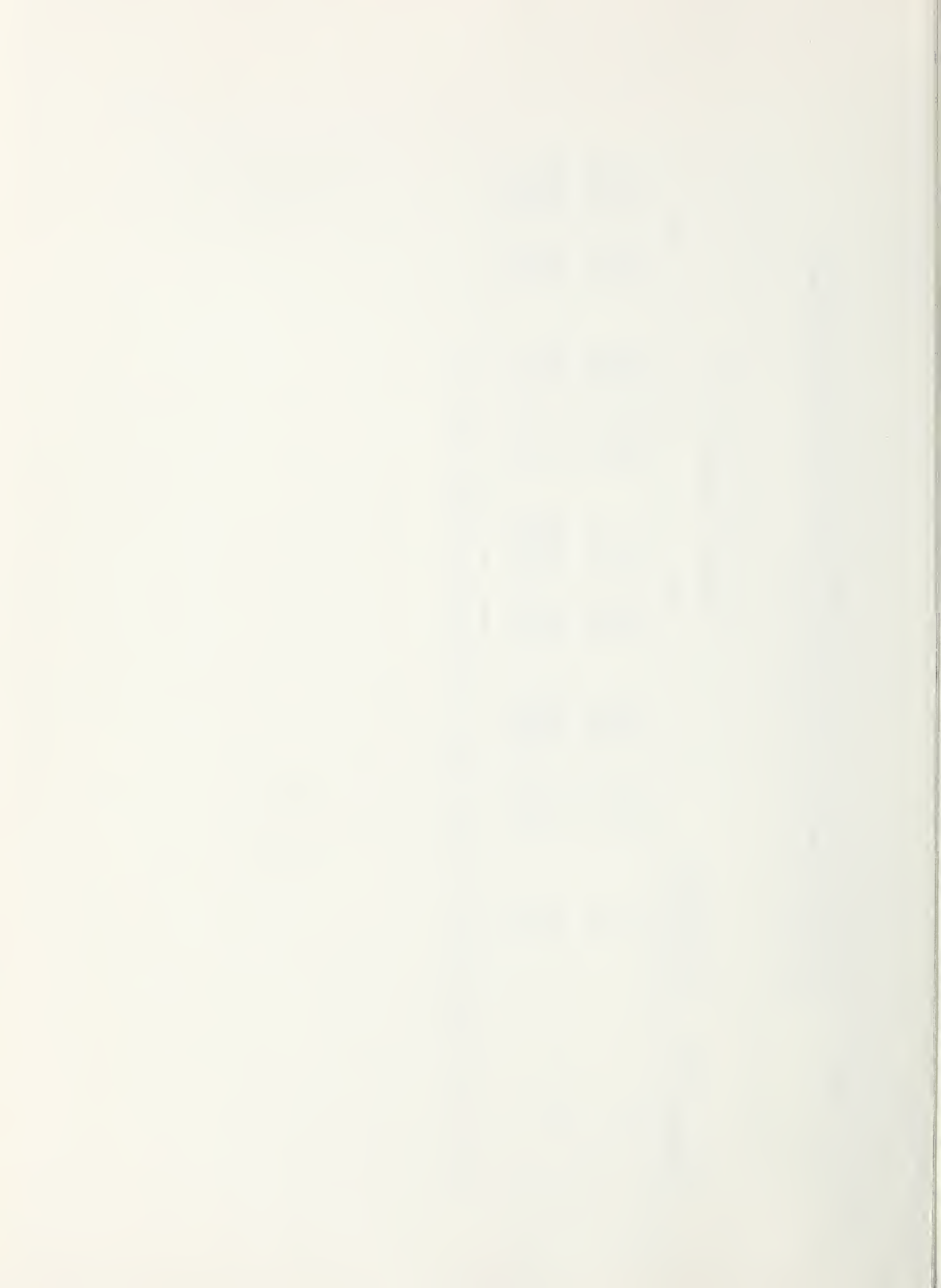




Table 28. General table illustrating the sensory scores for freezer burn on frozen beef roasts throughout storage and according to final storage temperature and rate of freezing - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Immediately after freezing, 1 day		4.09 $\pm$ .64	3.75 $\pm$ .85	4.37 $\pm$ .55	4.4 $\pm$ .74
6 months	-10T	4.05 $\pm$ .51	3.65 $\pm$ .74	3.12 $\pm$ 1.15	3.44 $\pm$ .63
	0T	3.75 $\pm$ .72	3.80 $\pm$ .70	3.25 $\pm$ .68	3.25 $\pm$ .77
	20T	3.1 $\pm$ .91	3.15 $\pm$ .99	3.19 $\pm$ .65	3.62 $\pm$ .50
9 months	-10T	3.33 $\pm$ .89	2.67 $\pm$ .65	3.19 $\pm$ .40	3.9 $\pm$ .79
	0T	3.45 $\pm$ .81	3.42 $\pm$ .67	3.67 $\pm$ .61	3.6 $\pm$ .60
	20T	3.68 $\pm$ .60	3.00 $\pm$ .60	3.06 $\pm$ .47	2.92 $\pm$ .29
12 months	-10T	3.75 $\pm$ .75	3.50 $\pm$ .63	3.79 $\pm$ .97	3.87 $\pm$ .99
	0T	4.25 $\pm$ .75	3.52 $\pm$ .85	4.10 $\pm$ .53	3.4 $\pm$ .94
	20T	4.33 $\pm$ .78	3.65 $\pm$ .50	4.04 $\pm$ .86	2.96 $\pm$ .73
	20N	3.50 $\pm$ .52	--	3.00 $\pm$ .74	2.75 $\pm$ .46

<sup>a</sup>Mean  $\pm$  S.D.; T = Temperature abused; N = Not temperature abused.

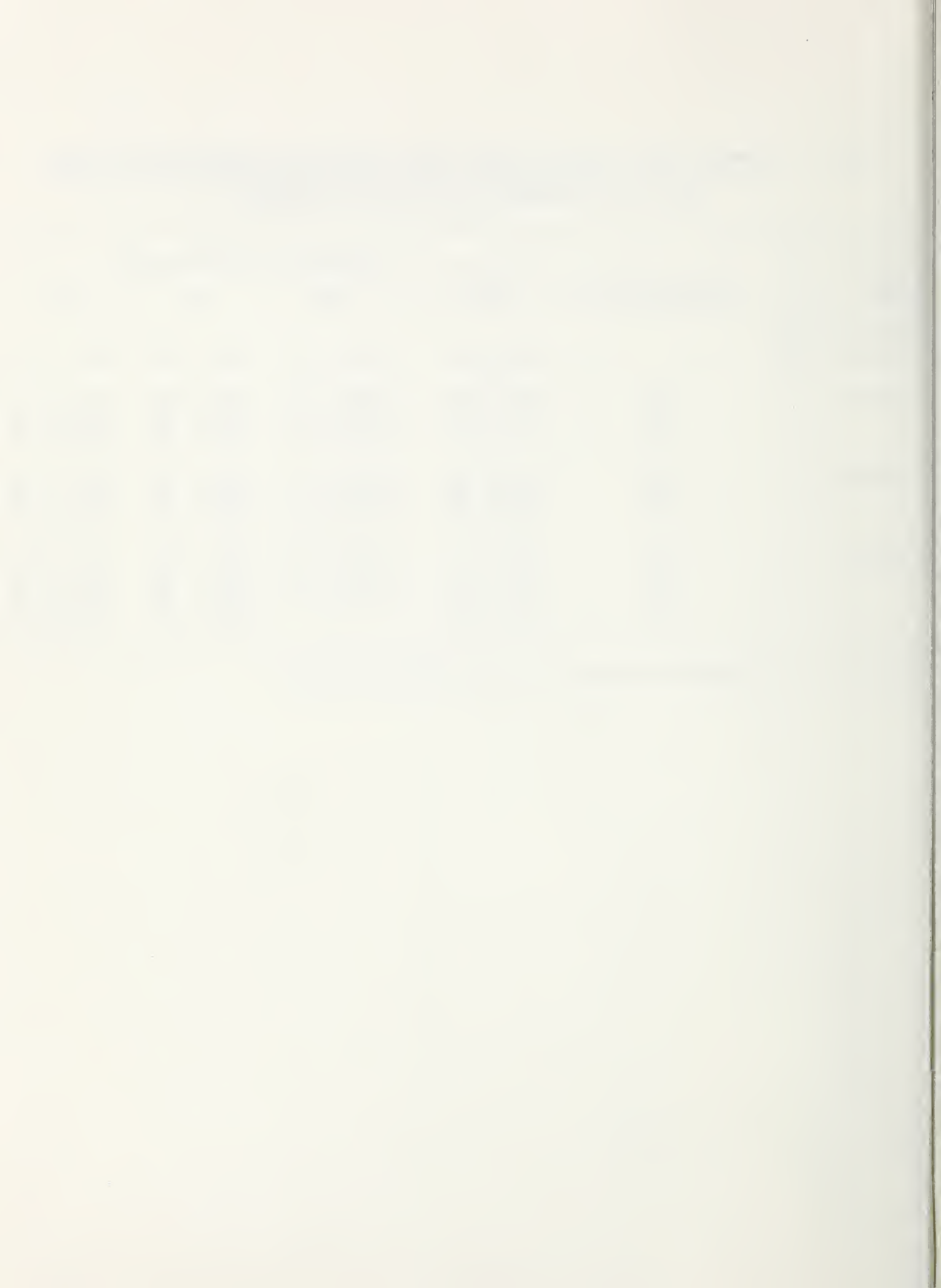


Table 29. Effect of various storage time comparisons on sensory scores for freezer burn on frozen beef roasts

Evaluation times	
Immediately following freezing, 1 day	6 months
4.23 $\pm$ .16a	3.45 $\pm$ .16b
Immediately following freezing, 1 day	9 months
4.23 $\pm$ .15a	3.32 $\pm$ .15b
9 months	12 months
3.32 $\pm$ .089b	3.76 $\pm$ .089a

ab Means on the same line with different letters are different ( $P < .05$ );  
Mean  $\pm$  S.E.



Table 30 . Interaction effect of final storage temperature and initial storage temperature on sensory scores for freezer burn on frozen beef roasts following twelve months of storage<sup>a</sup>

Final Storage Temperature, °F	Initial storage temperature, °F	
	-10	0
-10	3.47 $\pm$ .21	3.99 $\pm$ .21
0	3.99 $\pm$ .21	3.66 $\pm$ .21
+20	4.16 $\pm$ .21	3.32 $\pm$ .21

<sup>a</sup>Interaction significant by Analysis of Variance, but not by HSD. Mean  $\pm$  S.E.

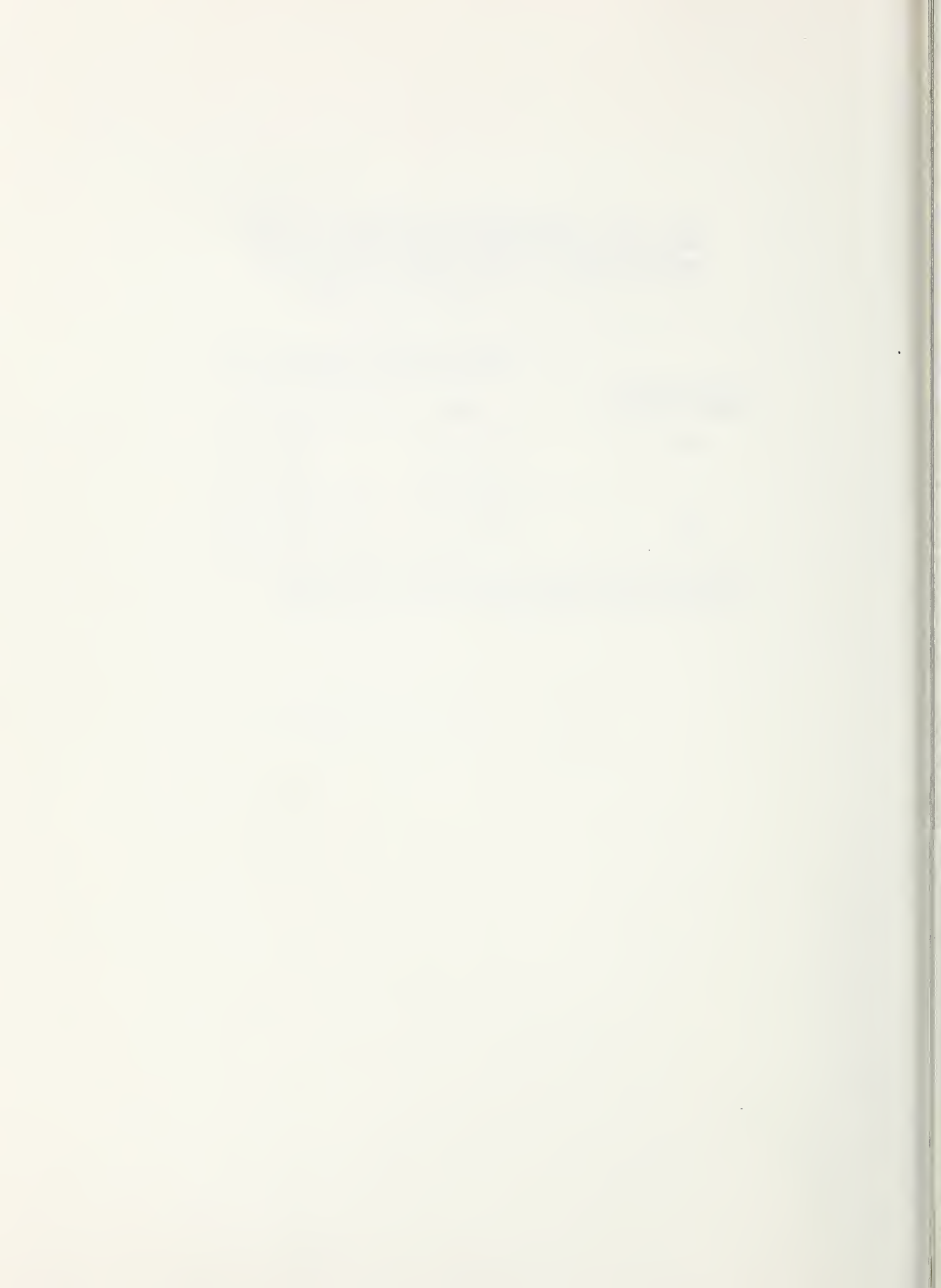


Table 31. Effect of freezing rate on sensory scores for freezer burn on frozen beef roasts following twelve months storage

Freezing Rate, hours to 0°F			
24	48	72	96
4.11 $\pm$ .17a	3.55 $\pm$ .17ab	3.96 $\pm$ .17ab	3.41 $\pm$ .17b

ab Means on the same line with the same letters are not different ( $P > .05$ ); Mean  $\pm$  S.E.

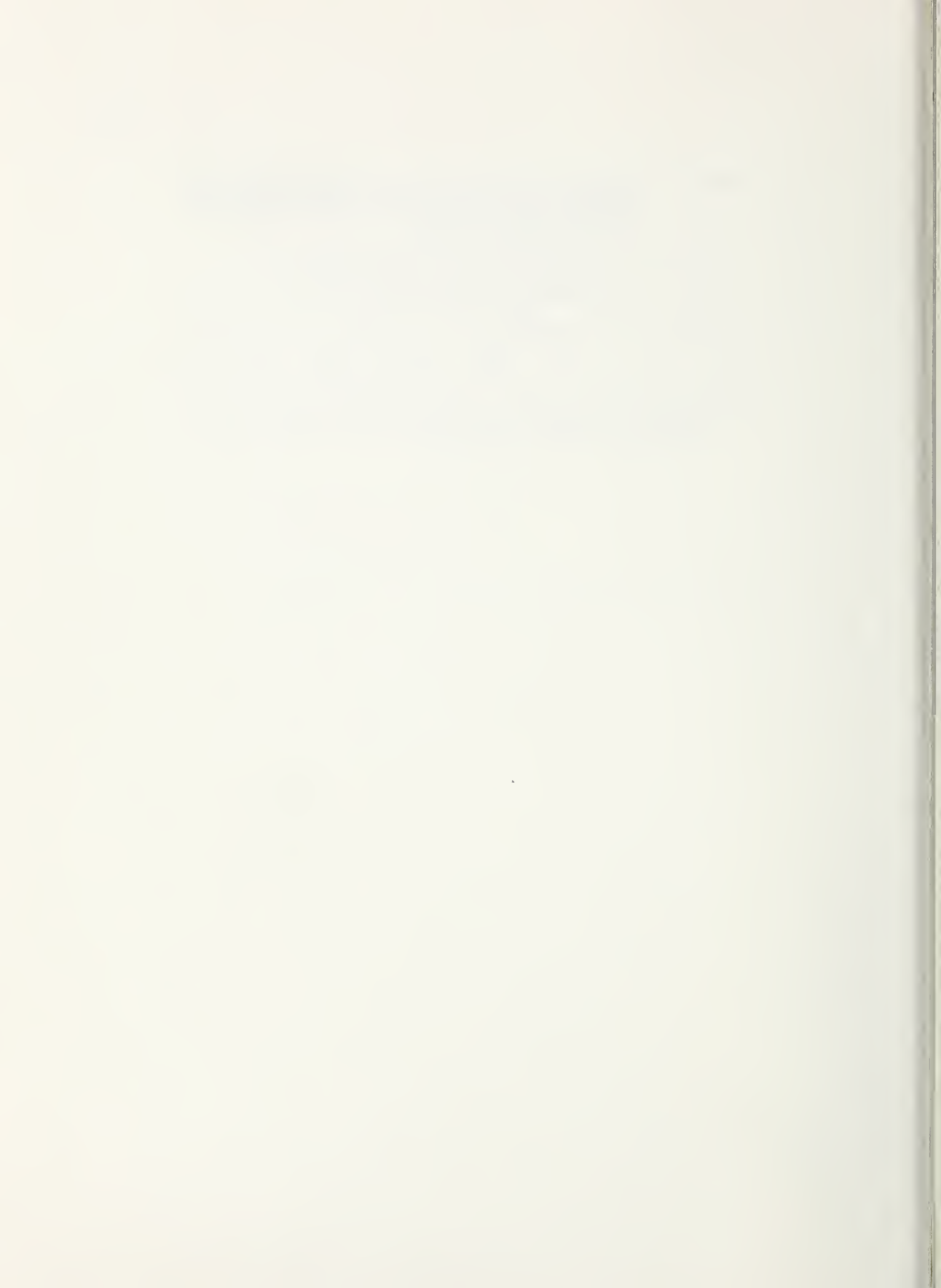
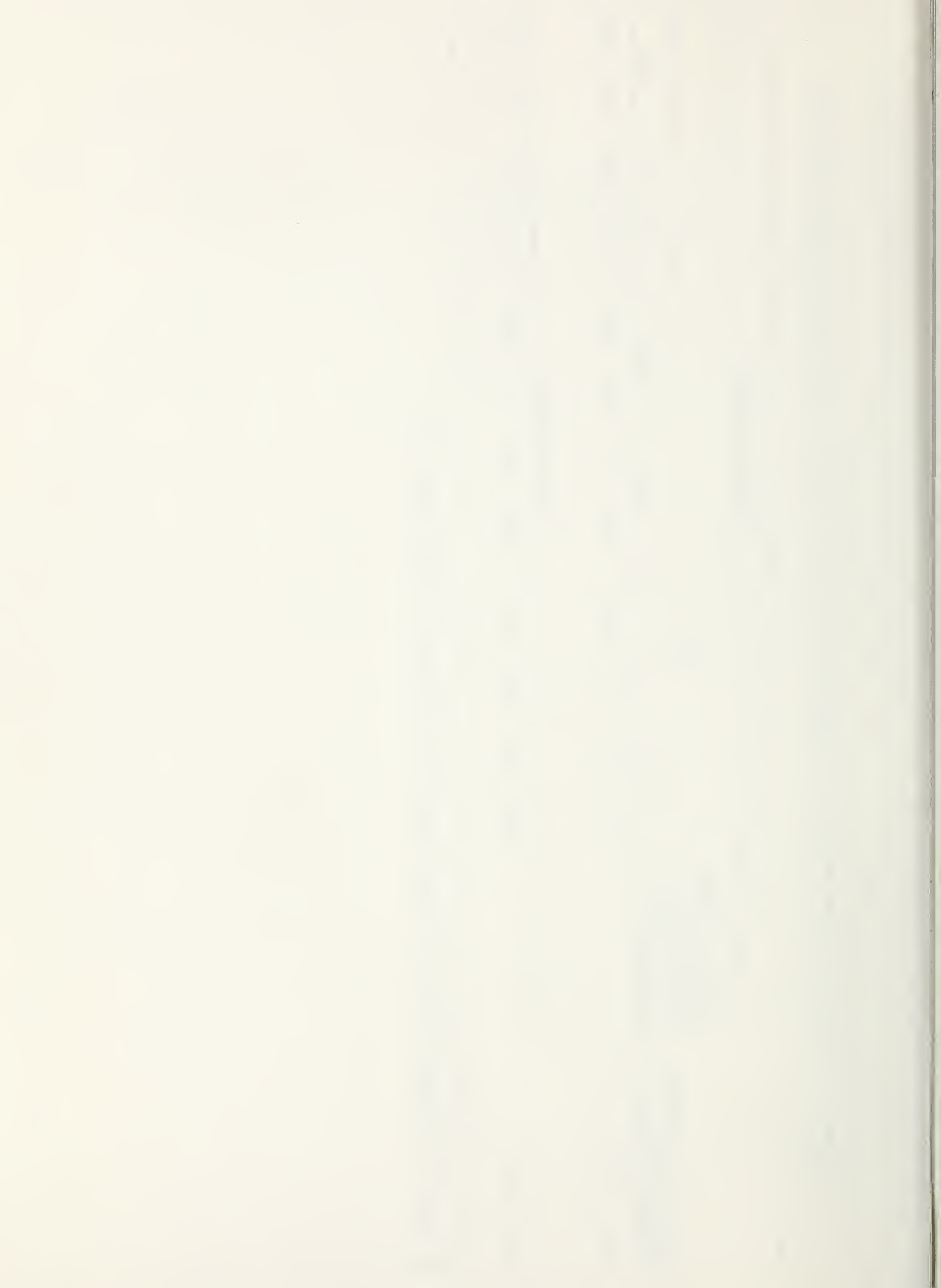




Table 32. Effect of various storage time comparisons on sensory scores for freezer burn on frozen beef roasts

		12 months storage					
Immediately following freezing, 1 day	Initial Storage temperature, °F =	-10			0		
	Final Storage temperature, °F =	-10	0	20	-10	0	20
4.23 + .15a		3.14 + .25b	3.36 + .25ab	3.09 + .25b	3.99 + .25ab	3.67 + .25ab	3.44 + .25ab
9 months storage							
4.23 + .13a		3.02 + .22b	3.61 + .22ab	2.98 + .22b	3.52 + .22ab	3.46 + .22ab	3.35 + .22b

ab Means on the same line with the same letters are not different ( $P > .05$ ); Mean + S.E.



+20°F final temperature combination differed in surface discoloration from that scored just after freezing. Both -10°F initial and -10°F final and -10°F initial and +20°F final temperatures increased in surface discoloration. At twelve months, the exact same differences occurred except none of the 0°F initial and various final temperature combinations increased in surface discoloration on thawed roasts over that noted right after freezing.

Off-odor scores in linear mean and standard deviation format throughout the study are given in Table 33. Storage time seems to be the major variable causing an increase in off-odor. Off-odor significantly ( $P < .05$ ) increased at all storage times over that noted right after freezing (Table 34, 35). Before initiation of freezing, roasts selected for freezing to 0°F in 24 hr had more off-odor than roasts selected for the 0°F in 72 and 96 hr (Table 36). After six months of storage, roasts stored at +20°F had more off-odor than roasts held at the other two temperatures (Table 37). This paralleled the differences in surface discoloration noted at this storage time attributable to final storage temperature.

After nine months storage, roasts initially stored at 0°F and finally stored at 0°F had less off-odor than roasts initially held at 0°F and finally stored at +20°F (Table 38). Following twelve months of storage, a significant ( $P < .05$ ) interaction of initial storage temperature, final storage temperature and rate of freezing was found for off-odor (Table 39). The major factor resulting in this interaction appears to be the greater off-odor in roasts frozen to 0°F in 24 hr, initially stored at -10°F and finally stored at either 0 or -10°F compared to similar initial and final storage temperatures for 0°F in 48 hr roasts and +20°F stored roasts under the same initial temperature and freezing rate.



Table 33. General table illustrating sensory scores for off-odor in beef roasts throughout storage and according to final storage temperature and rate of freezing - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		3.87 ± .34	3.97 ± .16	4.0 ± 0.0	4.00 ± 0.0
Immediately after freezing, 1 day		3.87 ± .28	3.92 ± .28	3.90 ± .30	3.95 ± .22
6 months	-10T	2.25 ± .64	2.94 ± .57	2.70 ± .66	2.22 ± .43
	0T	2.45 ± .60	2.94 ± .57	2.8 ± .47	2.17 ± .38
	20T	2.00 ± .56	2.00 ± .52	2.2 ± .41	2.10 ± .32
9 months	-10T	2.25 ± .61	2.76 ± .65	2.25 ± .58	2.35 ± .59
	0T	2.5 ± .48	2.65 ± .59	2.32 ± .48	2.20 ± .52
	20T	1.92 ± .49	2.30 ± .66	1.82 ± .38	2.20 ± .52
12 months	-10T	2.08 ± .78	3.10 ± .45	2.25 ± .45	2.00 ± .52
	0T	2.08 ± .88	2.84 ± .38	1.94 ± .68	2.19 ± .54
	20T	1.90 ± .62	2.10 ± .47	2.06 ± .25	2.00 ± .36
	20W	2.37 ± .50	2.62 ± .62	2.00 ± .36	2.37 ± .50

<sup>a</sup>Mean ± S.D.; T = Temperature abused; N = Not temperature abused.

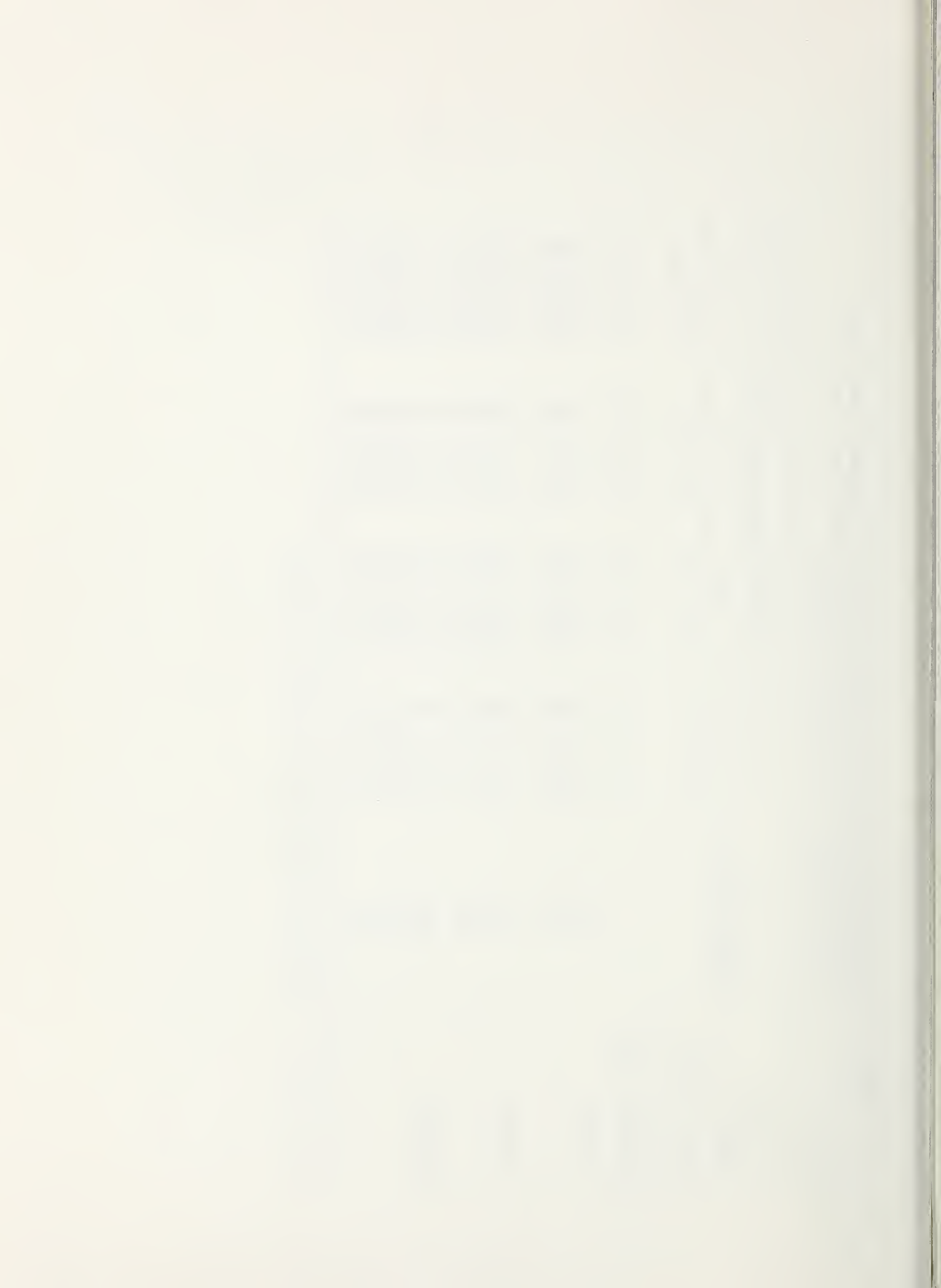


Table 34 . Effects of various storage time comparisons on sensory scores for off-odor in beef roasts

Evaluation time	
Immediately following freezing, 1 day	6 months
3.91 $\pm$ .068a	2.40 $\pm$ .068b
Immediately following freezing, 1 day	9 months
3.91 $\pm$ .10a	2.29 $\pm$ .10b
Immediately following freezing, 1 day	12 months <sup>C</sup>
3.91 $\pm$ .066a	2.21 $\pm$ .066b

ab Differences between means on the same line are significant ( $P < .05$ ). Mean  $\pm$  S.E.

<sup>C</sup>Includes just temperature abused product.

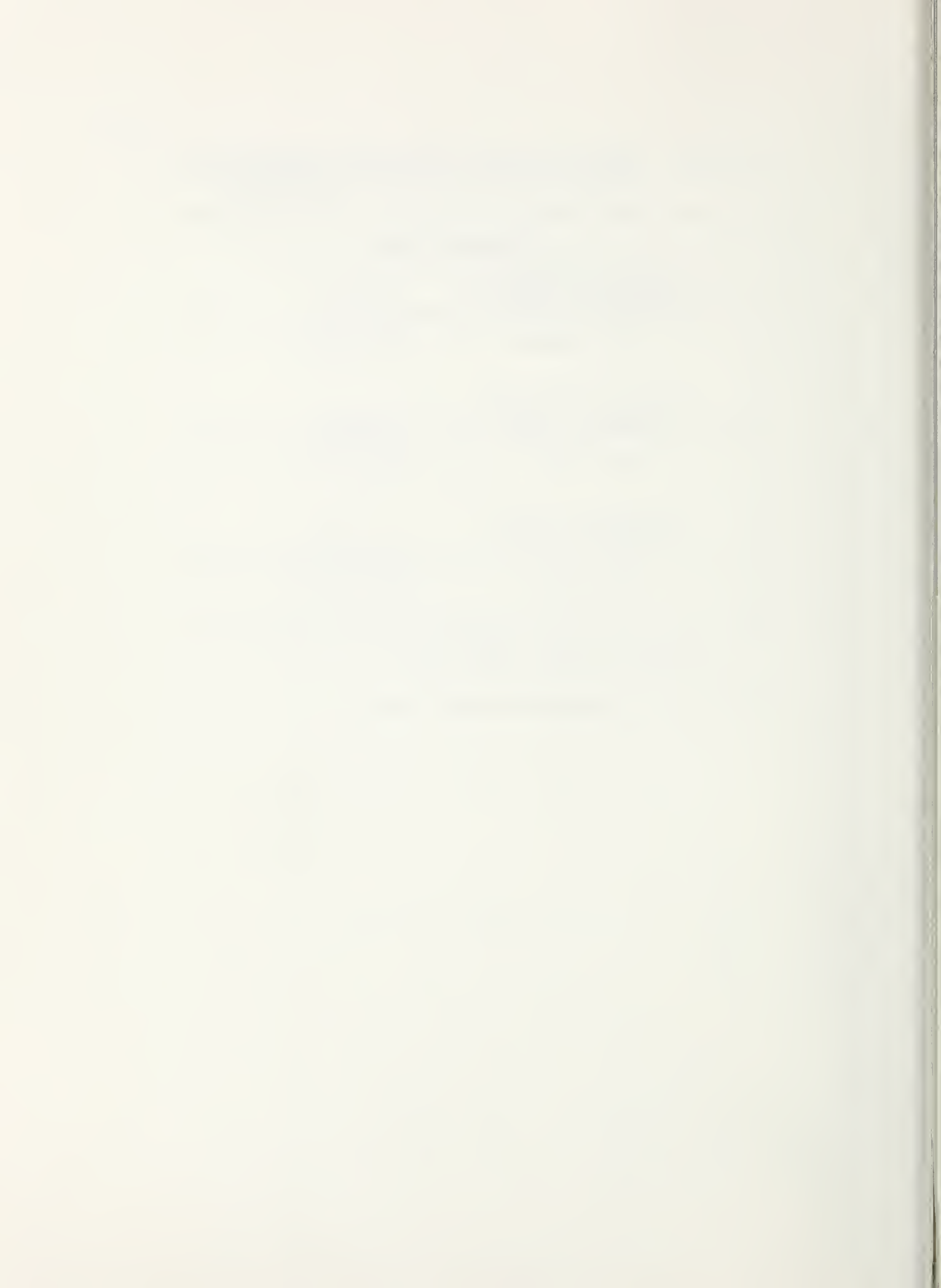




Table 35. Effect of storage time (immediately following freezing, twelve months) on sensory scores for off-odor in beef roasts

Evaluation times	
Immediately following freezing, 1 day	12 months <sup>C</sup>
3.91 $\pm$ .061a	2.18 $\pm$ .061b

ab Difference between means significant ( $P < .05$ ).  
mean  $\pm$  S.E..

<sup>C</sup>Includes just 0°F in 96 hour freezing rate.



Table 36. Interaction effect of storage time (six, nine months) and rate of freezing on sensory scores for off-odor in beef roasts

Evaluation time	Freezing rate, hours to °F			
	24	48	72	96
Just before freezing	3.87 $\pm$ .027b	3.97 $\pm$ .027ab	4.0 $\pm$ .027a	4.0 $\pm$ .027a
6 months <sup>C</sup>	2.23 $\pm$ .11	2.62 $\pm$ .11	2.57 $\pm$ .11	2.17 $\pm$ .11

Means on the same line with the same letters are not different ( $P > .05$ ). Mean  $\pm$  S.E. differences due to freezing rate significant ( $P < .05$ ) through analyses of variance, but not HSD.

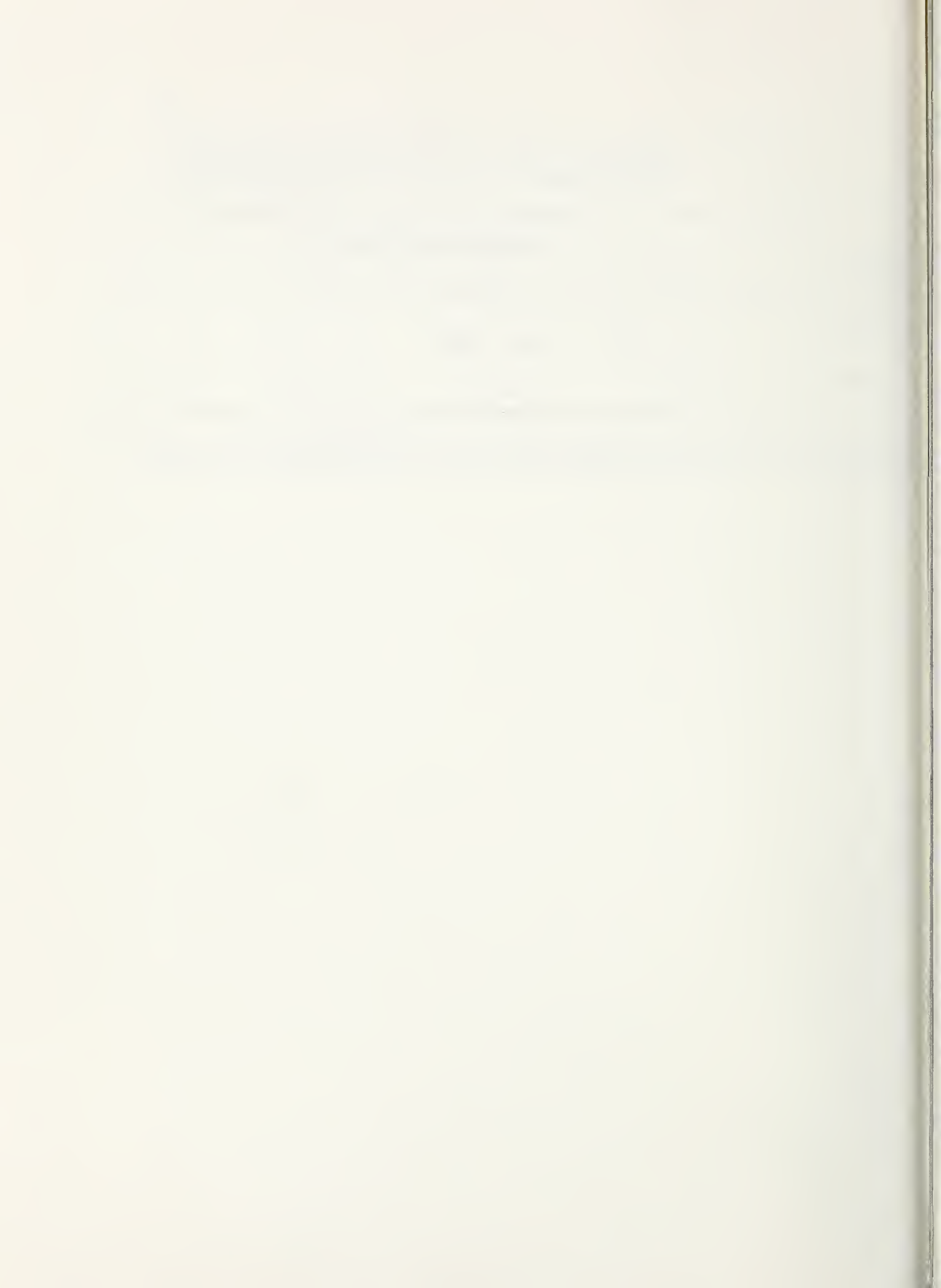


Table 37. Effect of final storage temperature on sensory scores for off-odor in beef roasts following six months storage

Final storage temperature, °F		
-10	0	20
2.53 $\pm$ .076a	2.59 $\pm$ .076a	2.07 $\pm$ .076b

ab Means on the same line with different letters are not different ( $P < .05$ ); Mean  $\pm$  S.E.

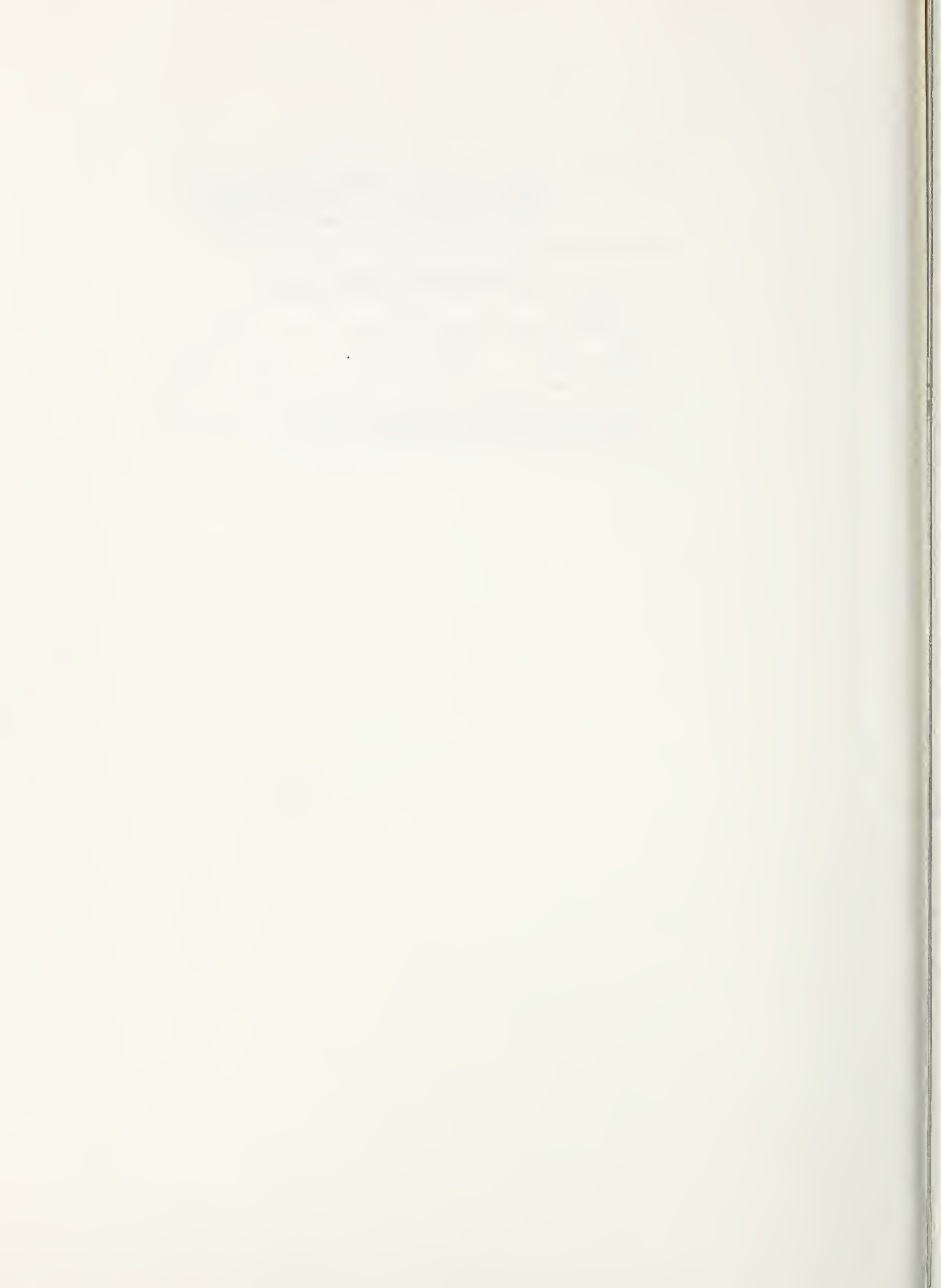


Table 38 . Interaction effect of initial storage temperature and final storage temperature on sensory scores for off-odor in beef roasts following nine months storage

Initial storage temperature, °F	Final storage temperature, °F		
	-10	0	20
-10	2.41 $\pm$ .12ab	2.25 $\pm$ .12ab	2.23 $\pm$ .12ab
0	2.40 $\pm$ .12ab	2.58 $\pm$ .12a	1.89 $\pm$ .12b

ab Any mean comparisons with the same letters are not different ( $P > .05$ ).  
Mean  $\pm$  S.E.

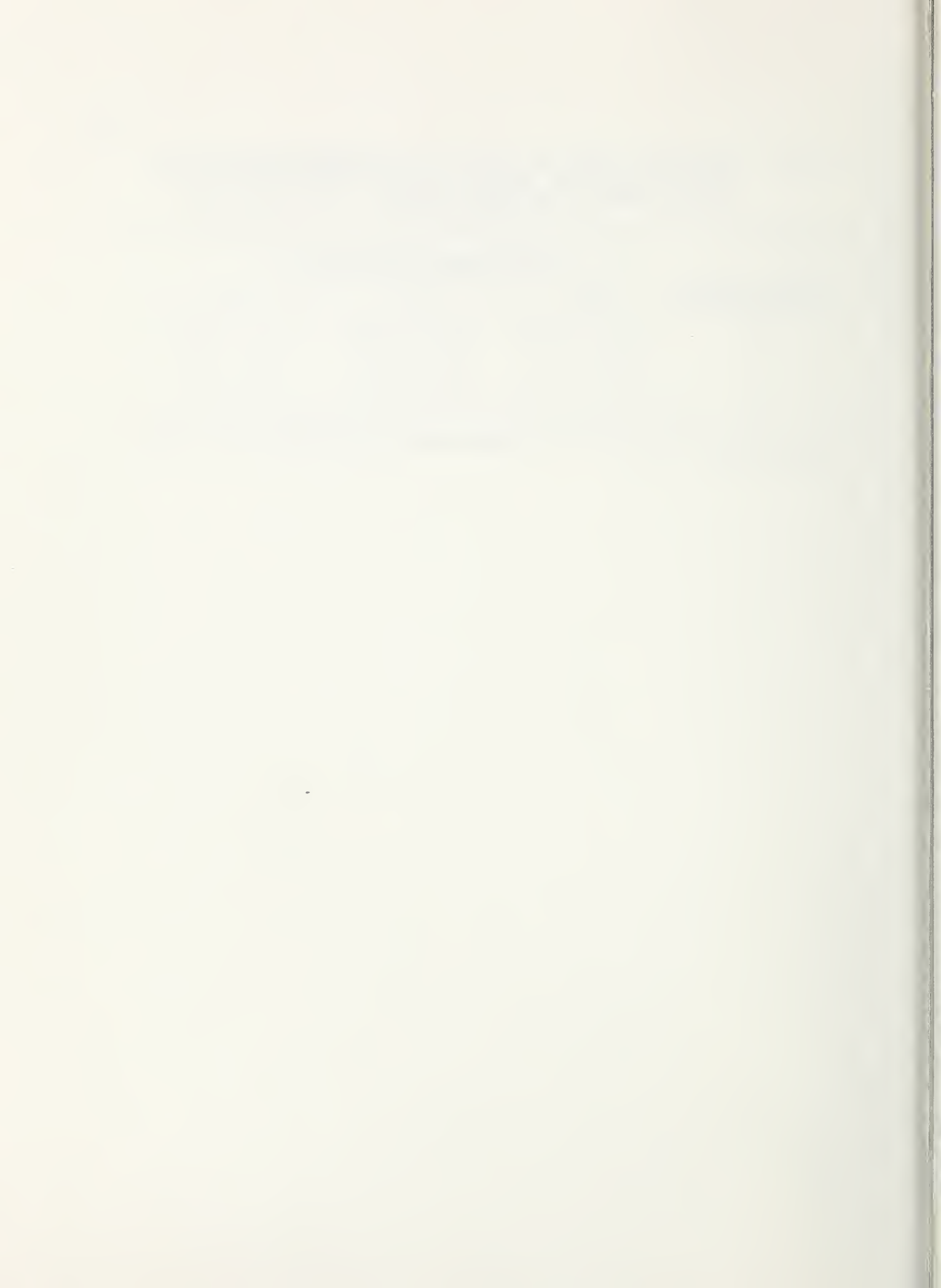




Table 39. Interaction effect of initial storage temperature, final storage temperature and rate of freezing on sensory scores for off-odor in beef roasts following twelve months storage

Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
-10	-10	1.5 + .2e	3.2 + .2a	2.25 + .2abcde	2.12 + .2abcde
	0	1.5 + .2e	2.8 + .2abc	1.62 + .2de	2.37 + .2abcde
	20	2.12 + .2abcde	2.2 + .2abcde	2.0 + .2abcde	2.12 + .2abcde
0	-10	2.67 + .2abcde	3.0 + .2ab	2.25 + .2abcde	1.87 + .2bcde
	0	2.67 + .2abcde	2.87 + .2abc	2.25 + .2abcde	2.0 + .2abcde
	20	1.67 + .2cde	2.0 + .2abcde	2.12 + .2abcde	1.87 + .2bcde

abcde Any mean comparisons with different letters are different ( $P < .05$ ); Mean  $\pm$  S.E.



Temperature-abused roasts were found to have more off-odor at twelve months (Table 40). Temperature-abused roasts also were more discolored at twelve months. Roasts stored for twelve months had more off-odor (Table 41). A four-way interaction involving storage time (immediately following freezing twelve months) initial and final storage temperature and freezing rate was noted for off-odor (Table 41). This interaction again appears to be due to the high degree of off-odor in the roasts frozen to 0°F in 24 hr, initially stored at -10°F and finally stored at either -10°F or 0°F. Also, several of the initial-final storage temperature combinations for 0°F in 48 hr product did not possess more off-odor following twelve months compared to just after freezing.

TBA values for roasts expressed as linear means and standard deviations are presented in Table 42. Differences according to the design of the project were inconsistent. TBA values for roasts frozen to 0°F in 48 hr were unobtainable just before and after freezing. There was a decline in TBA values immediately following freezing to either 0°F in 24 and 72 hr, but not 96 hr (Table 43).

Comparisons of immediately following freezing with twelve months of storage revealed an increase in TBA values (Table 44). However, nine months of storage produced a decrease in TBA values compared to that found right after freezing.

Following six months of storage, 0°F in 96 hr frozen product displayed higher TBA values than 0°F in 48 or 72 hr if initially stored at -10°F. No differences were found in TBA values of roasts initially stored at 0°F (Table 45). In a significant ( $P < .05$ ) interaction of storage time (six, nine months) initial storage temperature and freezing rate for TBA, the interaction seems to center on the increase in TBA values from using 0°F



Table 40. Effect of temperature abuse on sensory scores for off-odor in beef roasts following twelve months storage

Temperature Abuse	
T	N
2.01 $\pm$ .07b	2.34 $\pm$ .07a

ab Difference between means significant ( $P < .05$ ).

T = temperature abused, N = not temperature abused.



Table 41. Interaction effect of storage time (immediately following freezing, twelve months) initial storage temperature, final storage temperature and rate of freezing on sensory scores for off-odor in beef roasts

Evaluation time	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to °F			
			24	48	72	96
Immediately after freezing, 1 day						
12 months	-10		4.0 ± .12a	3.83 ± .24ab	3.85 ± .12ab	3.95 ± .12a
		-10	1.50 ± .17g	3.20 ± .17abc	2.25 ± .17cdefg	2.12 ± .17cdefg
		0	1.50 ± .17g	2.80 ± .17bcde	1.62 ± .17fg	2.37 ± .17cdefg
	0	20	2.12 ± .17cdefg	2.20 ± .17cdefg	2.00 ± .17defg	2.12 ± .17cdefg
		-10	2.67 ± .24cdef	3.00 ± .17abcd	2.25 ± .17cdefg	1.87 ± .17defg
		0	2.33 ± .24cdefg	2.87 ± .17abcd	2.25 ± .17cdefg	2.00 ± .17defg
	20		1.67 ± .24efg	2.00 ± .17defg	2.12 ± .17cdefg	1.87 ± .17defg

abcdefg Any mean comparisons with the same letters are not different ( $P > .05$ ). Mean ± S.E.

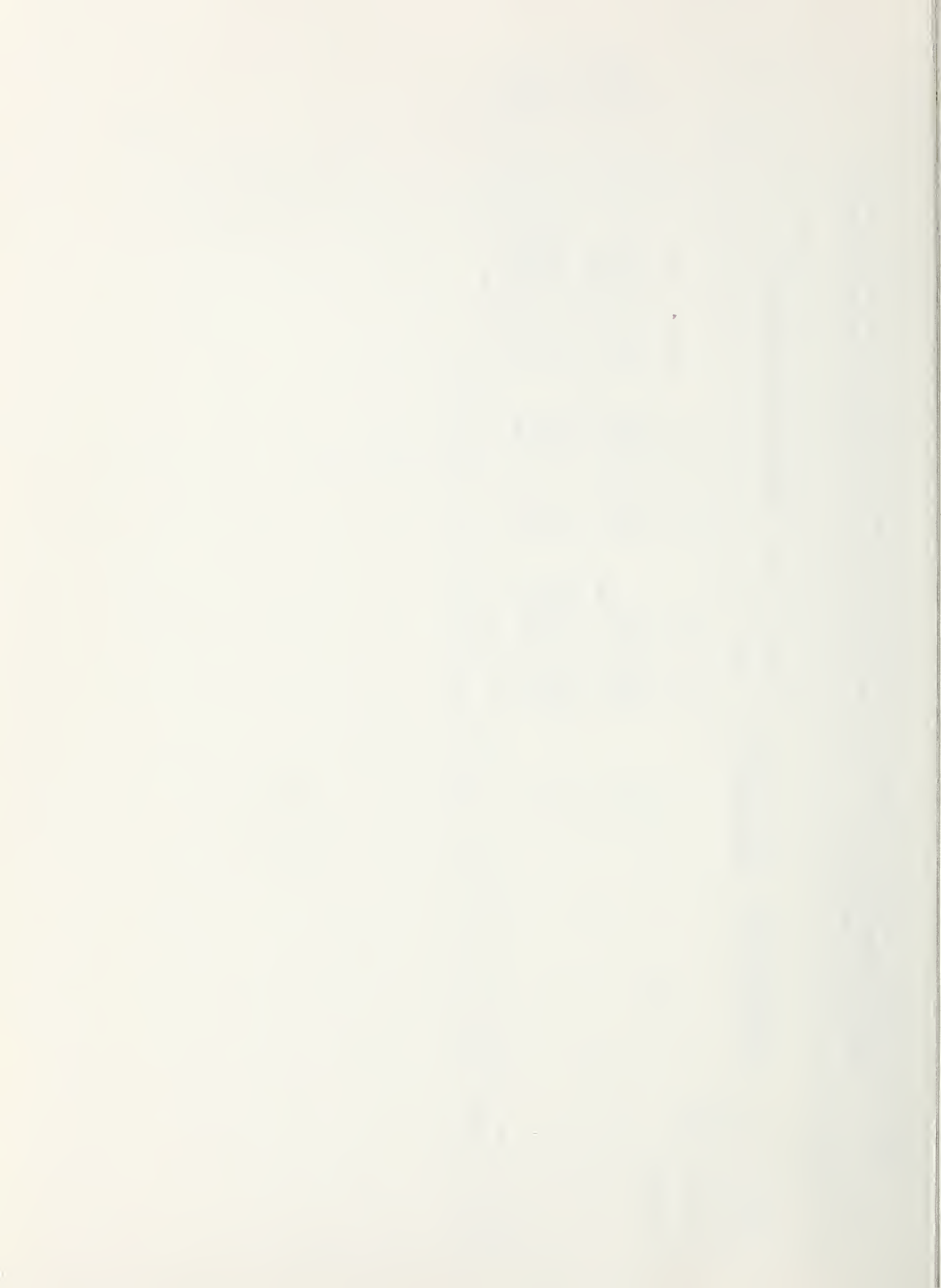




Table 42. General table illustrating TBA values for beef roasts throughout storage and according to final storage temperature and rate of freezing  
- no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		1.41 ± .31	--	1.48 ± .82	1.0 ± .26
Immediately after freezing, 1 day		1.02 ± .25	--	1.7 ± .69	1.17 ± .39
6 months	-10T	.90 ± .42	.62 ± .23	.95 ± .42	1.36 ± .35
	0T	1.11 ± .45	.82 ± .33	1.31 ± .59	1.67 ± .89
	20T	1.23 ± .32	1.02 ± .65	1.33 ± .45	1.63 ± .46
9 months	-10T	.99 ± .39	1.25 ± .73	.81 ± .19	.77 ± .26
	0T	.92 ± .37	1.0 ± .39	1.07 ± .47	1.01 ± .71
	20T	1.4 ± .59	1.95 ± .56	.76 ± .22	1.11 ± .4
12 months	-10T	1.89 ± .43	1.15 ± .56	1.85 ± .72	1.7 ± 1.1
	0T	2.17 ± 1.10	1.09 ± .47	2.34 ± 1.04	1.39 ± .50
	20T	2.24 ± .77	2.03 ± .60	1.63 ± .78	1.66 ± .55
	20N	1.37 ± .30	1.61 ± .48	1.02 ± .37	1.74 ± .62

<sup>a</sup>Mean ± S.D.; T = Temperature abused; N = Not temperature abused.

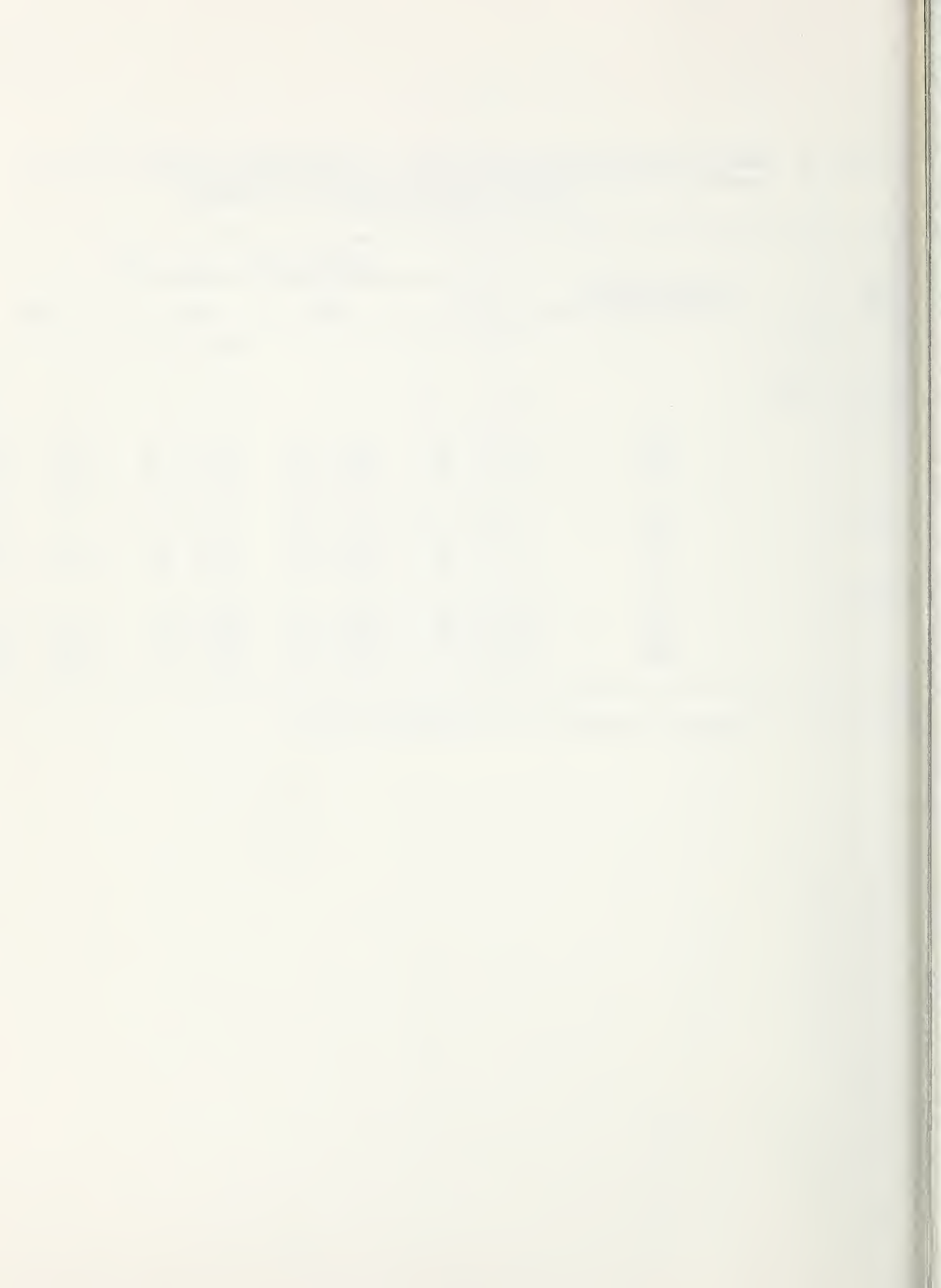


Table 43. Interaction effect of storage time (just before and after freezing) and rate of freezing on TBA values for beef roasts<sup>a</sup>

Evaluation time	Freezing rate, hours to °F		
	24	72	96
Before freezing	1.41 ± .11	1.48 ± .11	1.0 ± .11
Immediately following freezing, 1 day	1.02 ± .11	1.7 ± .11	1.17 ± .11

<sup>a</sup>Interaction significant ( $P < .05$ ) by analysis of variance but not by HSD; Mean ± S.E.



Table 44. Effect of various storage time comparisons on TBA values for beef roasts

Evaluation times	
Immediately following freezing, 1 day	9 months
1.36 $\pm$ .13a	0.98 $\pm$ .13b
9 months <sup>c</sup>	12 months
1.09 $\pm$ .082b	1.99 $\pm$ .082a
9 months <sup>d</sup>	12 months
.98 $\pm$ .081b	1.9 $\pm$ .081a
Immediately following freezing, 1 day	12 months
1.36 $\pm$ .19b	1.9 $\pm$ .19a
Immediately following freezing, 1 day	12 months <sup>e</sup>
1.30 $\pm$ .15b	1.76 $\pm$ .15a

ab Means on the same line with different letters are different ( $P < .05$ ); Mean  $\pm$  S.E.

<sup>c</sup>Includes only 0°F initial storage temperature product.

<sup>d</sup>Does not include 0°F in 48 hr product.

<sup>e</sup>Includes only +20°F final storage temperature.

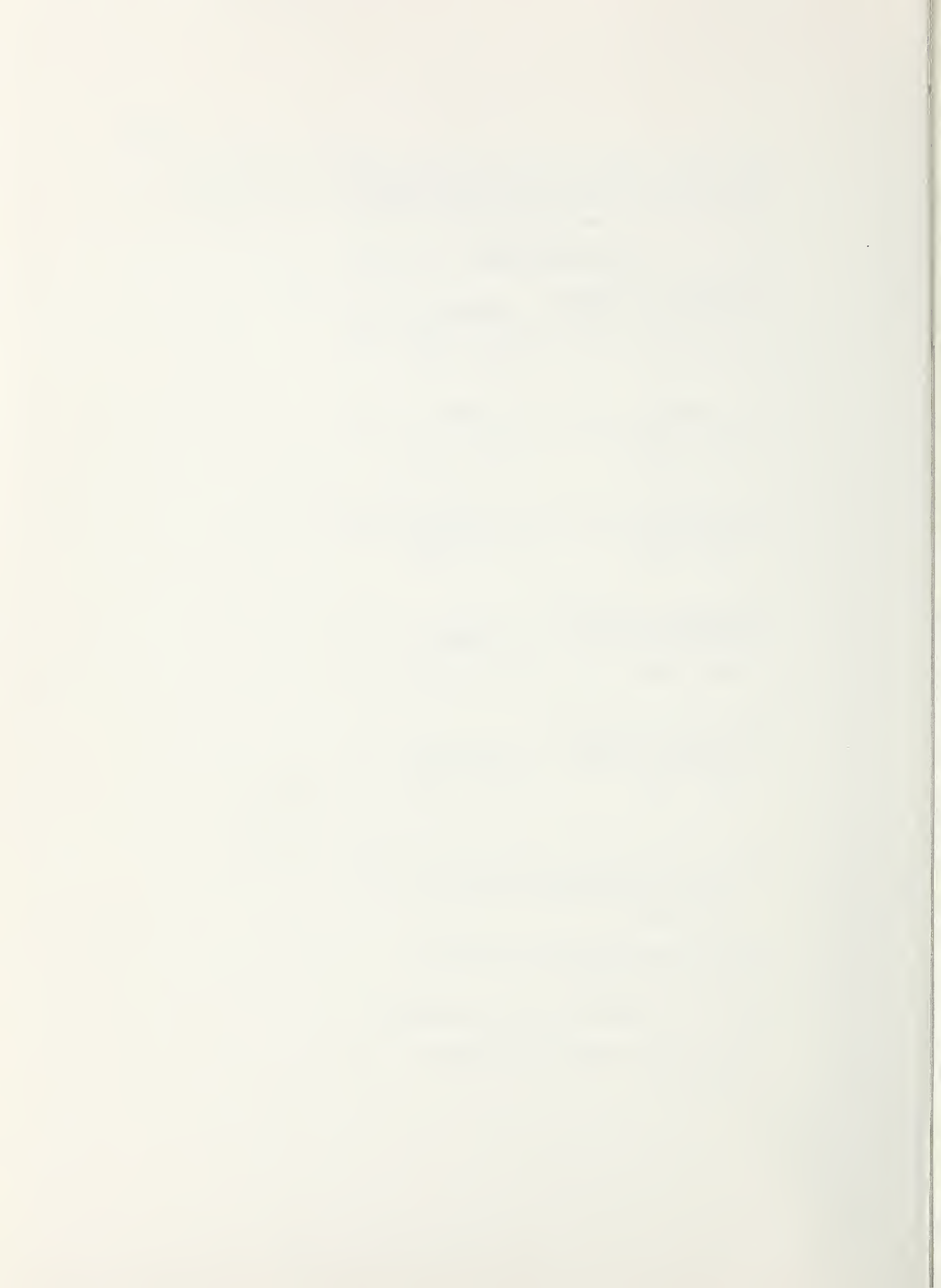
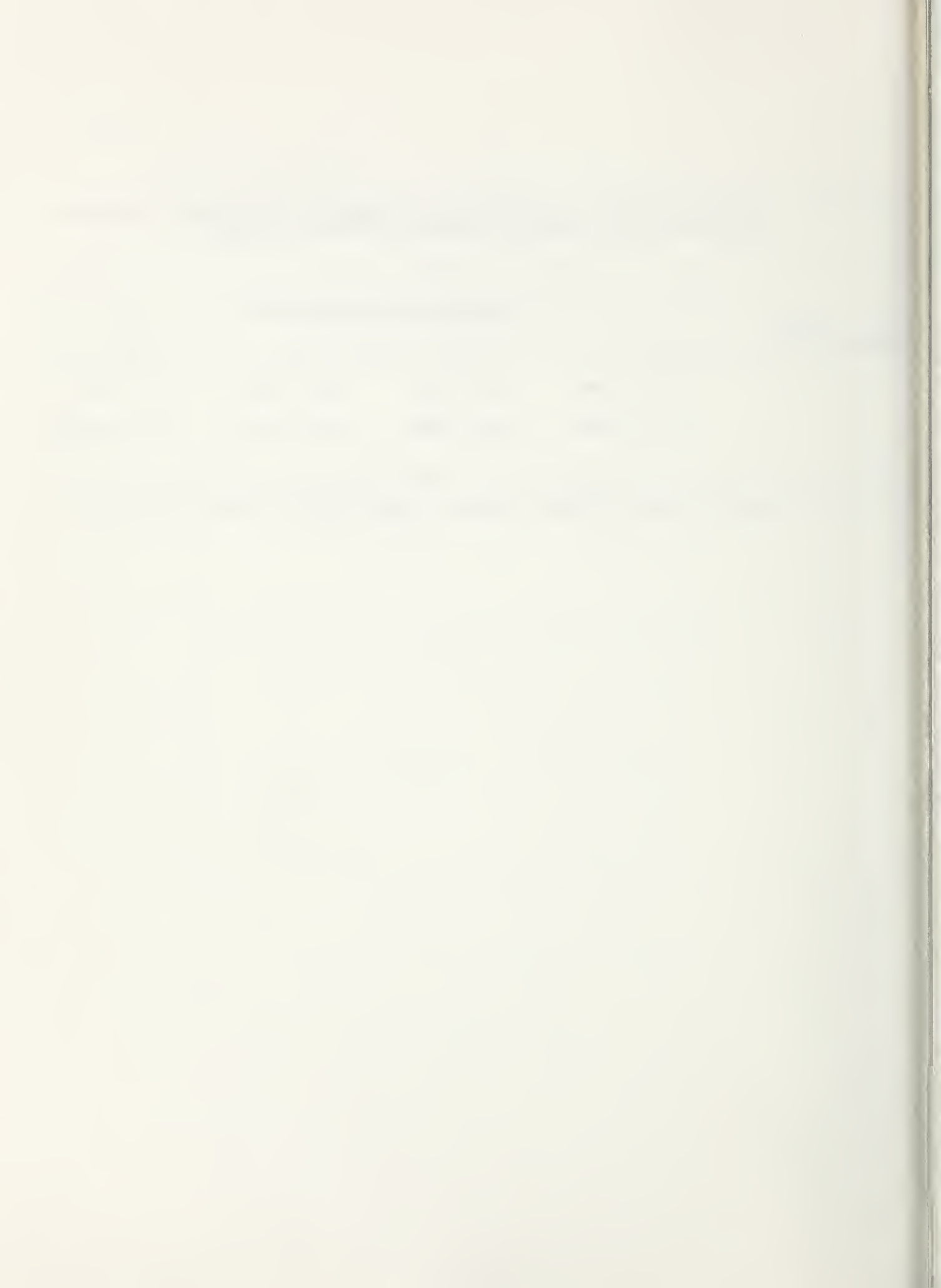


Table 45. Interaction effect of initial storage temperature and rate of freezing on TBA values for beef roasts following six months of storage

Initial storage temperature, °F-	Freezing rate, hours to 0°F			
	24	48	72	96
-10	1.05 $\pm$ .16abc	.64 $\pm$ .16c	.84 $\pm$ .16bc	1.8 $\pm$ .16a
0	1.11 $\pm$ .16abc	.99 $\pm$ .16bc	1.55 $\pm$ .16ab	1.31 $\pm$ .16abc

abc Any mean comparison with different letters is not different ( $P > .05$ ); Mean  $\pm$  S.E.





rather than  $-10^{\circ}\text{F}$  initial storage temperature, but only for  $0^{\circ}\text{F}$  in 72 hr at six months and  $0^{\circ}\text{F}$  in 24 and 72 hr at nine months (Table 46). At just nine months of storage (Table 47) roasts frozen to  $0^{\circ}\text{F}$  in 48 hr produced higher TBA values than roasts frozen to  $0^{\circ}\text{F}$  in 24 or 72 hr when they were initially stored at  $-10^{\circ}\text{F}$ . No freezing rate differences were found for roasts stored at  $0^{\circ}\text{F}$ .

An interaction involving just after freezing with nine months storage and including initial storage, final storage and freezing rate for TBA values is illustrated in Table 48. However, only a few differences were noted and the  $0^{\circ}\text{F}$  in 48 hr product could not be included in the comparisons.

After twelve months storage, roasts stored initially at  $0^{\circ}\text{F}$  contained higher TBA values than roasts stored initially at  $-10^{\circ}\text{F}$  (Table 49). Also, temperature abused product produced larger TBA values at twelve months than nonabused product (Table 50). These larger TBA values related to more off-odor on temperature abused roasts (Table 40). Immediately following freezing, roasts frozen to  $0^{\circ}\text{F}$  in 72 hr had higher TBA values than  $0^{\circ}\text{F}$  in 24 hr freezing rate roasts (Table 51). The opposite seemed to be true at twelve months, but differences were only significant ( $P < .05$ ) by analysis of variance and not HSD.

The next section of tables provides information on sensory values. From the general table of linear means, beef flavor intensity appeared to be influenced (reduced) by storage, but only slightly (Table 52). Increases in storage time (nine months vs right after freezing, twelve months vs both right after freezing and nine months) produced reductions in beef flavor intensity (Table 53). Obviously, some of these reductions were due to the increasing presence of other flavors as storage time progressed and which will be discussed later.



Table 46. Interaction effect of storage time (six, nine months), initial storage temperature and rate of freezing on TBA values for beef roasts

Evaluation time, months	Initial storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
6	-10	1.05 ± .093cde	.64 ± .32	.84 ± .093de	1.8 ± .093a
	0	1.11 ± .093bcde	.99 ± .51	1.55 ± .093ab	1.31 ± .093abcd
9	-10	.78 ± .093e	1.67 ± .63	.67 ± .093e	1.13 ± .093bcde
	0	1.43 ± .093abc	1.04 ± .64	1.09 ± .093bcde	.81 ± .093e

abcde Any mean comparisons with different letters are different ( $P < .05$ ); Mean ± S.E. Due to the use of different animals for 0°F in 48 hr frozen roasts at 9 months, the 0°F in 48 hr rate was not included in statistical analysis.

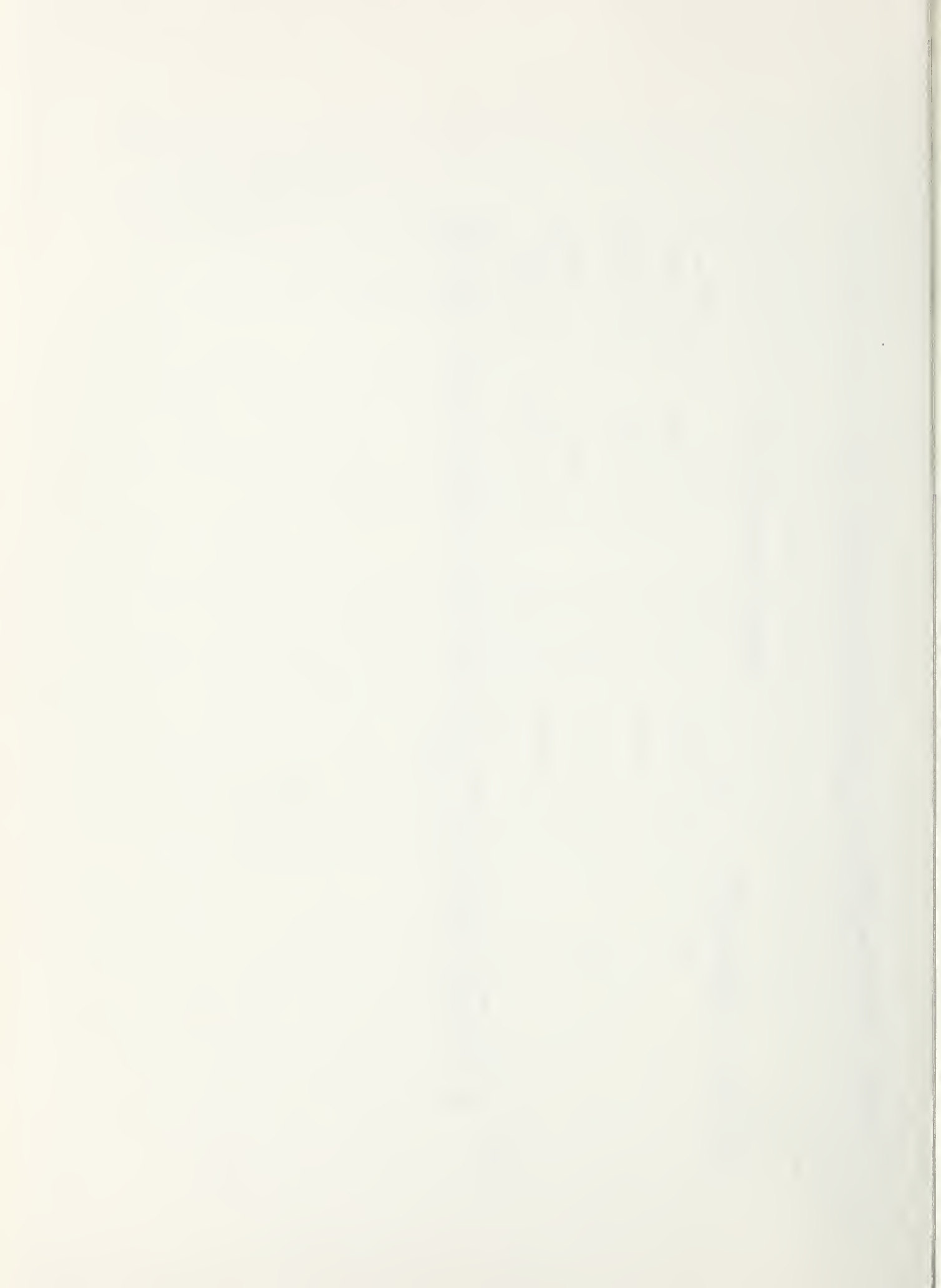


Table 47. Interaction effect of initial storage temperature and rate of freezing on TBA values for beef roasts following nine months of storage

Initial storage temperature, °F-	Freezing rate, hours to 0°F			
	24	48	72	96
-10	0.78 $\pm$ .18b	1.67 $\pm$ .18a	0.67 $\pm$ .18b	1.13 $\pm$ .18ab
0	1.43 $\pm$ .18ab	1.04 $\pm$ .18ab	1.09 $\pm$ .18ab	0.81 $\pm$ .18ab

ab Any mean comparisons with the same letters are not different ( $P>.05$ ); Mean  $\pm$  S.E.



Table 48. Interaction effect of storage time (immediately following freezing, nine months) and rate of freezing on TBA values for beef roasts

Evaluation time	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to °F			
			24	48	72	96
Immediately after freezing, 1 day			1.06 ± .20ab	--	1.98 ± .20a	1.04 ± .20ab
9 months	-10	-10	0.59 ± .34ab	1.69 ± .60	1.28 ± .34ab	0.74 ± .34ab
		0	0.59 ± .34ab	1.25 ± .44	1.30 ± .34ab	1.24 ± .34ab
		+20	0.93 ± .34ab	2.07 ± .67	1.27 ± .34ab	1.44 ± .34ab
	0	-10	1.39 ± .34ab	0.56 ± .11	0.34 ± .34b	0.80 ± .34ab
		0	1.25 ± .34ab	0.75 ± .55	0.84 ± .34ab	0.80 ± .34ab
		+20	1.88 ± .34a	1.83 ± .49	0.26 ± .34b	0.79 ± .34ab

ab Any mean comparisons with the same letters are not different ( $P > .05$ ); Mean ± S.E.





Table 49. Effect of initial storage temperature on TBA values for beef roasts following twelve months of storage

Initial storage temperature, °F	
-10	0
1.47 $\pm$ .089b	1.85 $\pm$ .089a

ab Difference between means significant ( $P < .05$ ); Mean  $\pm$  S.E.; 20°F final storage temperature only.

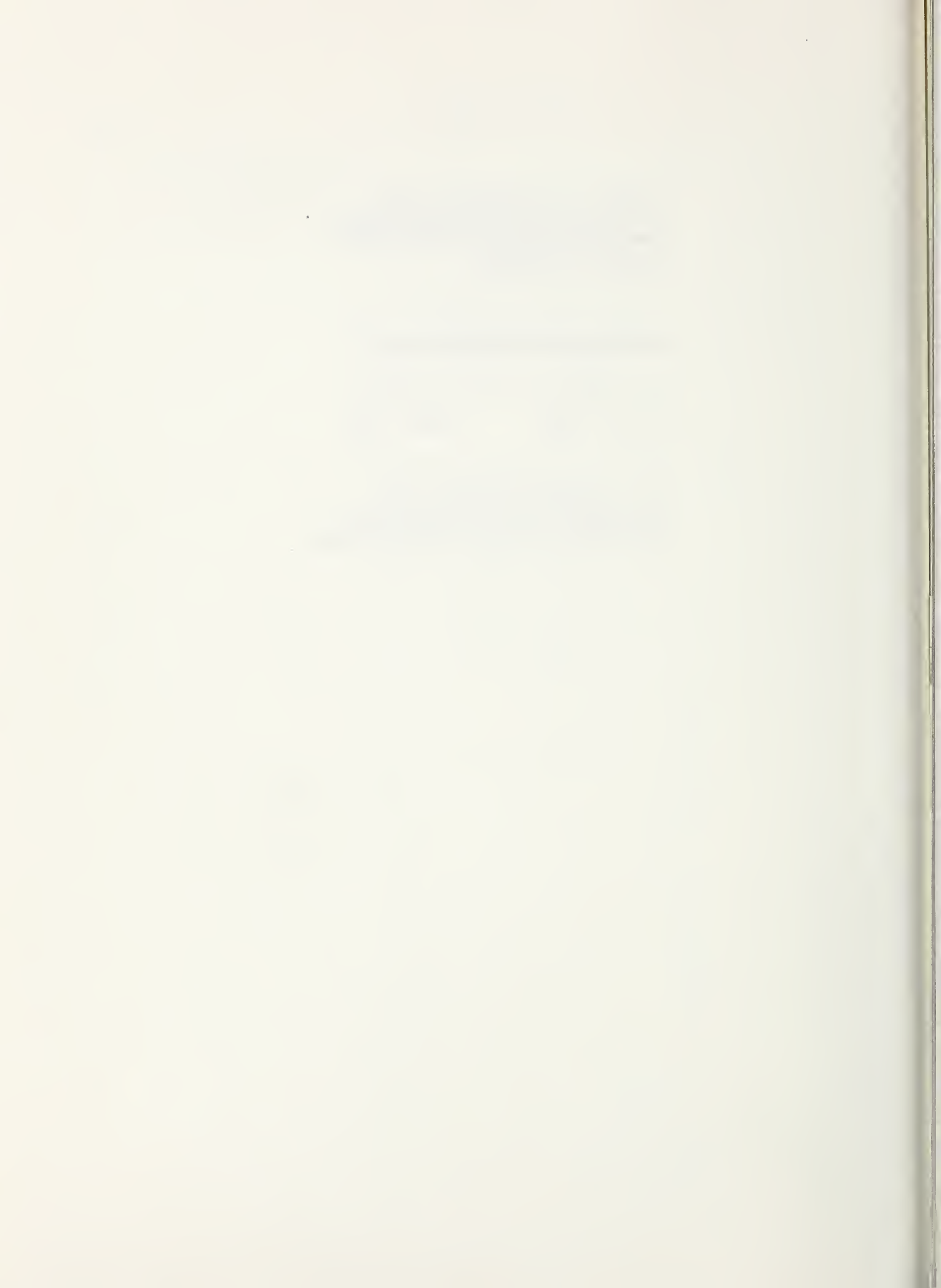


Table 50. Effect of temperature abuse on TBA values for beef roasts following twelve months of storage

Temperature abuse	
T	N
1.89 $\pm$ .089a	1.44 $\pm$ .089b

ab Difference between means significant ( $P < .05$ ); Mean  $\pm$  S.E.;  
 T = Temperature abused;  
 N = Not temperature abused.



Table 51. Effect of freezing rate at various storage times on TBA values for beef roasts

Evaluation time	Freezing rate, hours to 0°F			
	24	48	72	96
Immediately following freezing, 1 day	1.02 $\pm$ .16b	--	1.70 $\pm$ .16a	1.17 $\pm$ .16ab
12 months <sup>C</sup>	1.80 $\pm$ .12	1.82 $\pm$ .12	1.32 $\pm$ .12	1.70 $\pm$ .12

ab Means on the same line with the same letters are not different ( $P > .05$ ); Mean  $\pm$  S.E. No data obtained for 0°F in 48 h frozen beef roasts just following freezing.

<sup>C</sup>Differences due to freezing rate significant ( $P < .05$ ) by analysis of variance, but not by HSD.

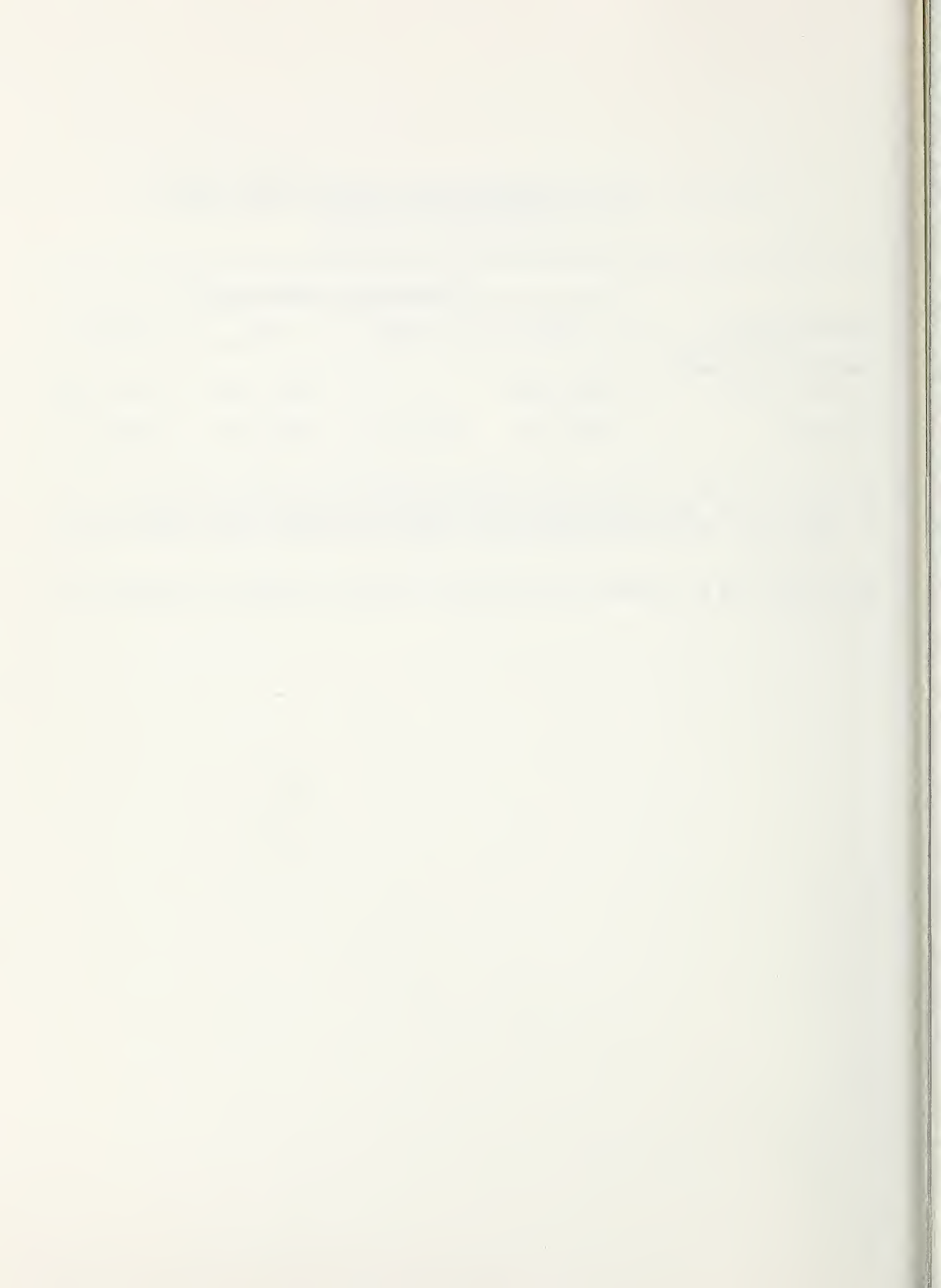


Table 52. General table illustrating sensory scores for roast beef flavor intensity in beef roasts throughout storage and according to final storage temperature and rate of freezing - no statistical analyses<sup>d</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		4.84 ± .91	5.29 ± .98	4.95 ± .90	4.65 ± 1.07
Immediately after freezing, 1 day		4.56 ± 1.27	4.78 ± 1.05	4.84 ± 1.13	4.61 ± 1.14
6 months	-10T	4.6 ± 1.13	4.67 ± .96	4.34 ± 1.11	4.72 ± 1.18
	0T	4.87 ± 1.28	4.55 ± .80	4.27 ± 1.2	4.67 ± 1.1
	20T	4.52 ± .94	4.66 ± .99	4.89 ± 1.15	4.01 ± 1.01
9 months	-10T	4.67 ± .86	4.07 ± .98	4.21 ± .97	3.91 ± .64
	0T	4.27 ± 1.09	3.45 ± 1.13	4.06 ± 1.01	3.81 ± .70
	20T	3.95 ± .67	3.25 ± 1.06	4.39 ± .97	4.31 ± 1.08
12 months	-10T	4.06 ± .82	4.25 ± .66	3.99 ± 1.02	4.68 ± .68
	0T	4.38 ± .73	3.94 ± 1.03	4.31 ± 1.12	3.92 ± 1.14
	20T	4.22 ± 1.0	4.12 ± 1.15	3.91 ± .88	4.57 ± 1.19
	20N	3.45 ± 1.18	3.92 ± .88	3.7 ± .85	4.5 ± .84

<sup>a</sup>Mean ± S.D.; T = Temperature abused; N = Not temperature abused.





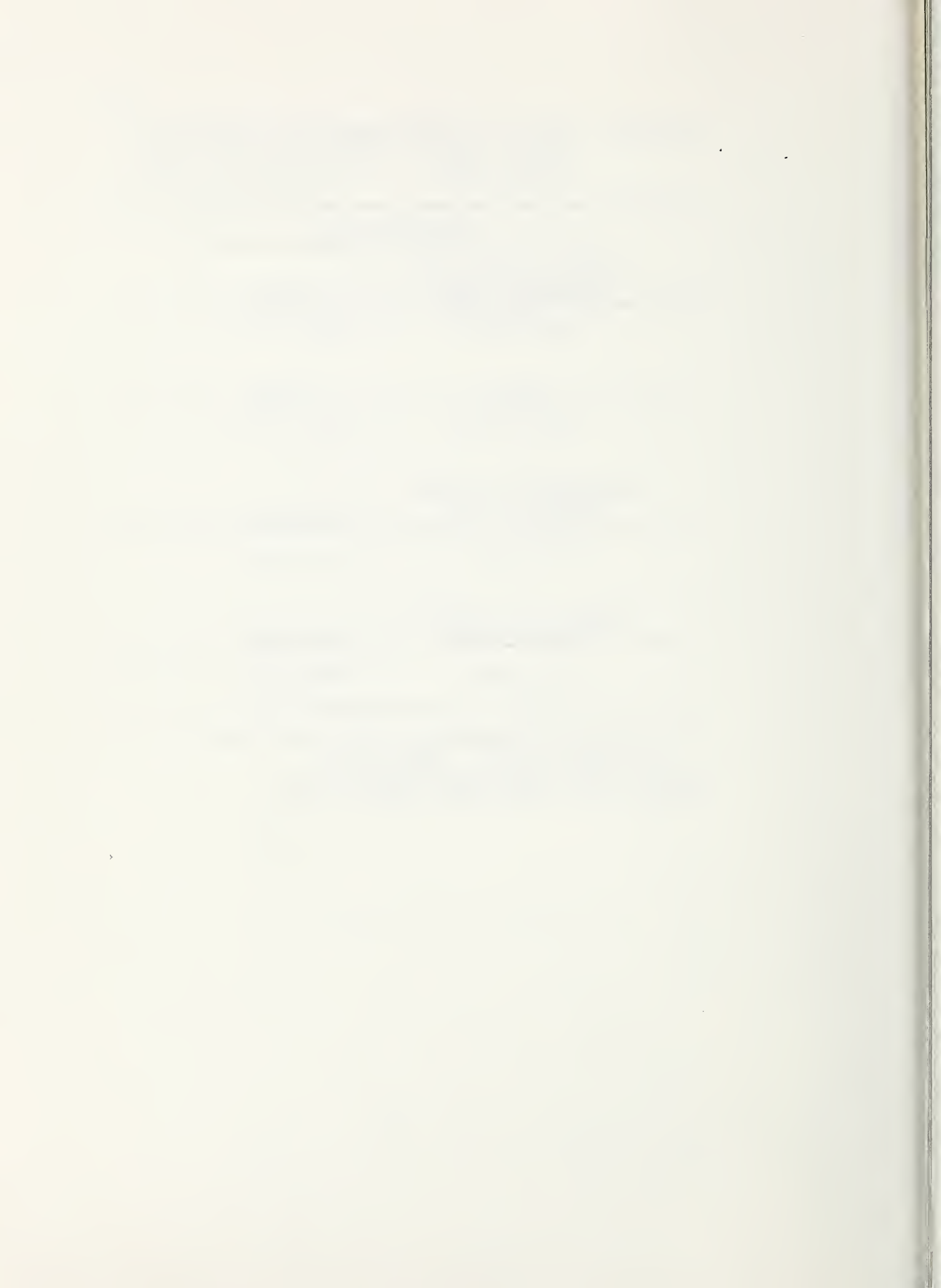
Table 53. Effect of various storage time comparisons on sensory scores for roast beef flavor intensity in beef roasts

Evaluation time	
Immediately following freezing, 1 day	9 months
4.77 $\pm$ .19a	4.03 $\pm$ .19b
6 months	9 months
4.56 $\pm$ .071a	4.03 $\pm$ .071b
Immediately following freezing, 1 day	12 months <sup>c</sup>
4.77 $\pm$ .19a	4.2 $\pm$ .19b
Immediately following freezing, 1 day	12 months <sup>d</sup>
4.77 $\pm$ .15a	4.05 $\pm$ .15b

ab Differences between means on the same line are significant ( $P < .05$ ). Mean  $\pm$  S.E.

<sup>c</sup>Includes only temperature abused product.

<sup>d</sup>Includes only +20°F stored product.



Compared to roast beef flavor intensity rated right after freezing, that evaluated at nine months was found to be lower for: 1) 0°F final stored product, regardless of initial temperature and, 2) +20°F final temperature product initially stored at -10°F (Table 54).

Significant ( $P < .05$ ) freezing rate effects were found for roast beef flavor at twelve months by analysis of variance, but not by HSD (Table 55). Roasts subjected to temperature abuse, initially stored at 0°F and evaluated at twelve months were found to have less roast beef flavor intensity than similar roasts that were nonabused (Table 56). Temperature abuse exerted no effects on roast flavor for roasts stored initially at -10°F.

Comparisons of roast beef flavor intensity just after freezing with those noted for various initial-final temperature combinations at twelve months are shown in Table 57. Only the roasts initially stored at -10°F and finally at +20°F were shown to have less beef flavor intensity than roasts cooked right after freezing. In an evaluation of an interaction (storage time, initial storage temperature, temperature abuse and freezing rate) at twelve months, most of the major effects seemed to center on temperature vs nontemperature abuse (Table 58). Nontemperature abused roasts frozen to 0°F in 96 hr, evaluated at twelve months and initially stored at -10°F were rated as having more intense beef flavor than temperature abused roasts from the same condition. In the case of roasts frozen to 0°F in 24 hr, initially stored at 0°F and evaluated at twelve months, temperature abuse produced more intense roast beef flavor than no temperature abuse.

Panelists found less incidence of metallic, but more evidence of rancid flavors in roasts evaluated at nine months and stored at +20°F compared to the other two storage temperatures (Table 59). At twelve

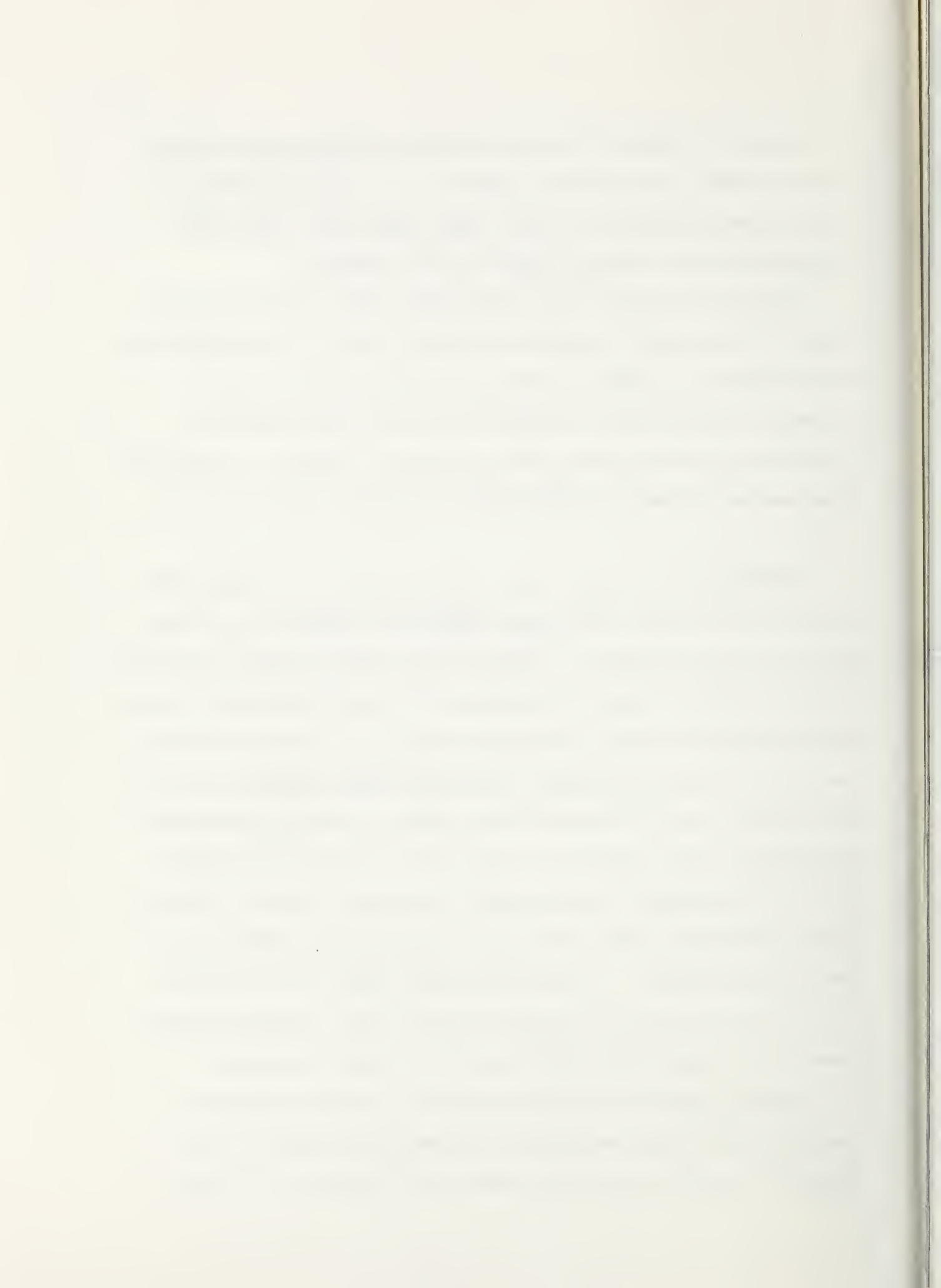


Table 54. Effect of storage time (immediately following freezing, nine months) on sensory scores for roast beef flavor intensity in beef roasts

		9 months storage			
		Initial storage temperature, °F =		-10	
				0	
		Final storage temperature, °F =		-10	
				20	
Immediately following freezing, 1 day	4.77 ± .12a	-10		0	
		4.06 ± .21ab		3.84 ± .21b	
				20	
				3.82 ± .21b	
				0	
				-10	
				3.95 ± .21b	
				4.13 ± .21ab	

ab Means on the same line with the same letters are not different ( $P > .05$ ); Mean ± S.E.



Table 55. Effect of freezing rate on roast beef flavor intensity scores in beef roasts following twelve months of storage<sup>a</sup>

Freezing rate, hours to 0°F			
24	48	72	96
3.83 ± .18	4.02 ± .18	3.80 ± .18	4.53 ± .18

<sup>a</sup>Differences due to freezing rate significant ( $P < .05$ ) by Analysis of Variance, but not by HSD test. Mean ± S.E.

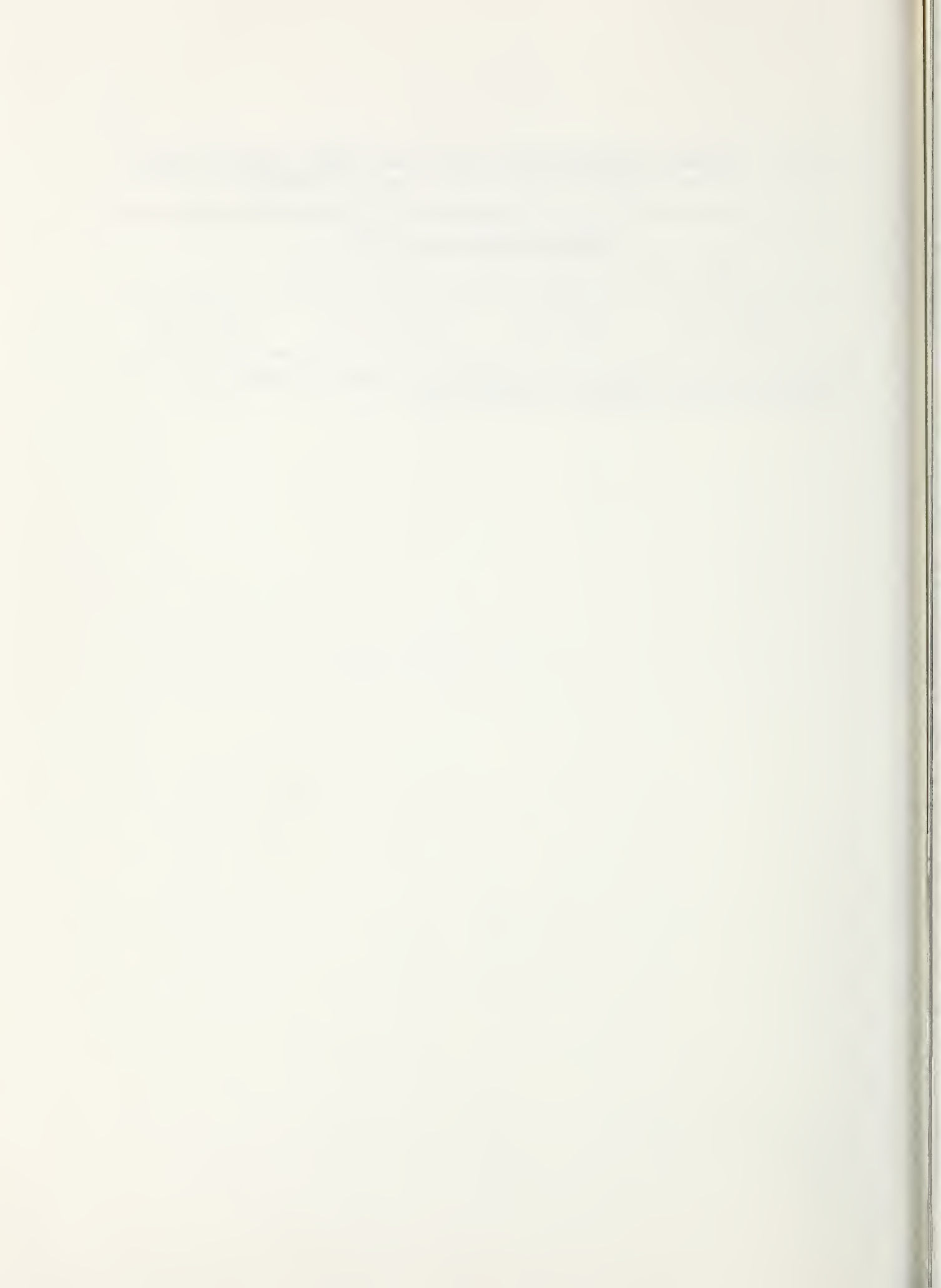




Table 56. Interaction effect of temperature abuse and initial storage temperature on sensory scores for roast beef flavor intensity in beef roasts following twelve months storage

Temperature abuse	Initial storage temperature, 0°F	
	-10	0
T	3.86 $\pm$ .18ab	4.55 $\pm$ .18a
N	4.01 $\pm$ .18ab	3.77 $\pm$ .18b

ab Any mean comparison with the same letters are not different ( $P > .05$ ); Mean  $\pm$  S.E.  
 T = temperature abused; N = not temperature abused.







Table 58. Interaction effect of storage time (immediately following freezing, twelve months) initial storage temperature, temperature abuse and rate of freezing on sensory scores for roast beef flavor intensity scores in beef roasts

Evaluation time	Initial storage temperature, °F	Temperature abuse	Freezing rate, hours to °F			
			24	48	72	96
Immediately after freezing, 1 day						
12 months	-10	T	4.56 ± .20abcd	4.78 ± .20abcd	4.84 ± .20abcd	4.61 ± .20abcd
		N	3.25 ± .52cd	4.18 ± .52abcd	3.55 ± .52bcd	3.66 ± .52bcd
	0	T	3.36 ± .52bcd	3.14 ± .52cd	4.64 ± .52abcd	6.16 ± .52a
		N	5.51 ± .52ab	4.76 ± .52abcd	2.99 ± .52d	5.2 ± .52abc
			3.23 ± .52cd	4.02 ± .52abcd	4.04 ± .52abcd	3.11 ± .52cd

ab Any mean comparisons with different letters are different ( $P < .05$ ). Mean ± S.E.

T = temperature abused; N = not temperature abused.

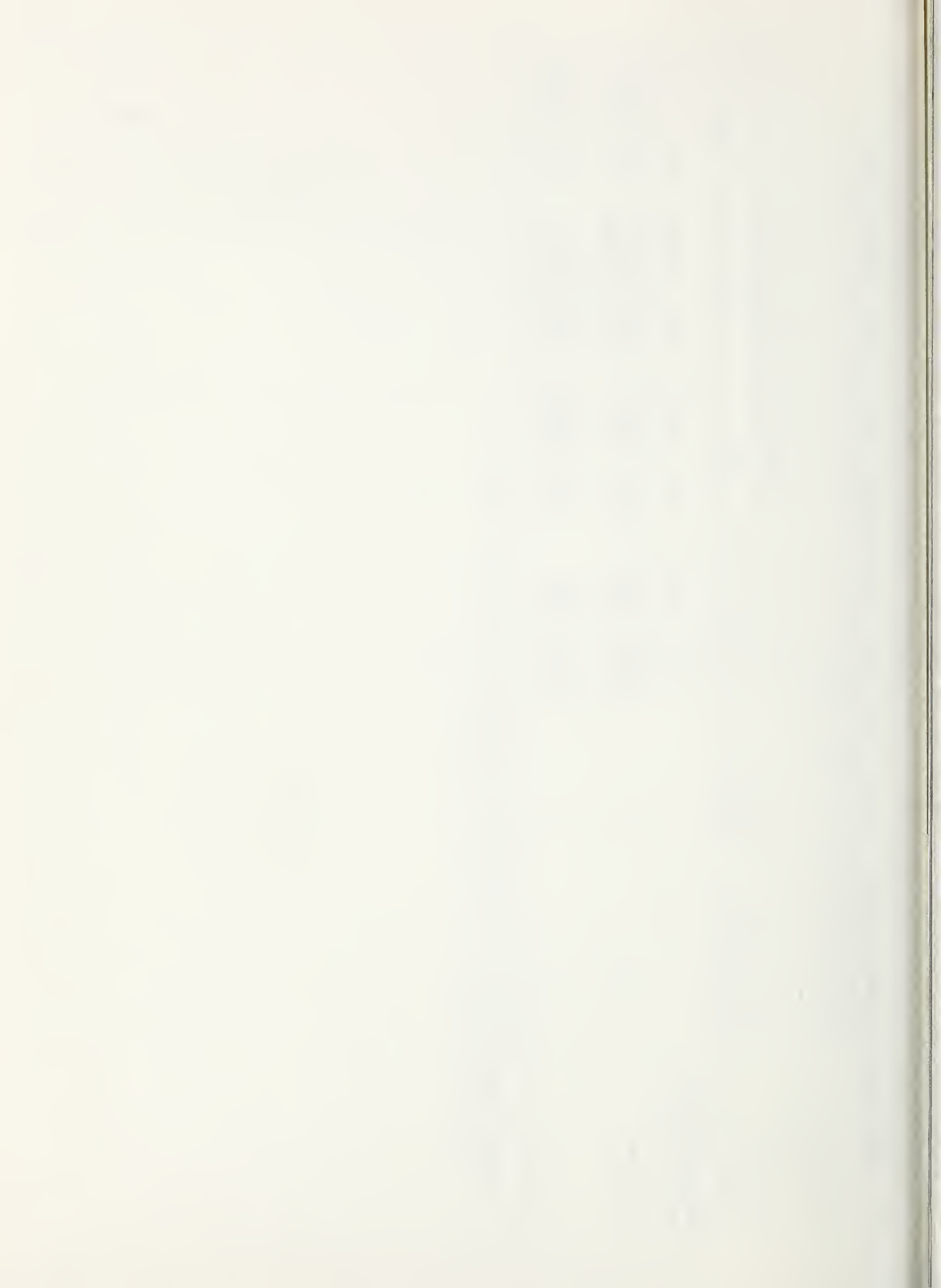


Table 59. Detectable flavor scores assigned to beef roasts according to final storage temperature following nine months storage<sup>a</sup>

Detectable Flavors	Final storage temperature, °F		
	-10	0	20
Sour	33.33	34.71	30.0
Bitter	12.28	12.40	16.43
Metallic	32.46	27.27	19.29
Rancid	10.53	12.4	25.0
Salty	0.00	1.65	.71
Other	11.40	11.57	8.57

Chi-square = 18.44,  $P < .048$

<sup>a</sup>Values are percentages of scores assigned within a final storage temperature.





months, panelists again found roasts stored at +20°F to have a higher frequency of rancid flavor, but also more bitter, less sour and less "other" flavors than roasts held at -10 and 0°F (Table 60). Off-odor and TBA values did not provide as much evidence of rancidity for the +20°F temperature.

As storage time progressed, the incidence of rancid flavor increased although certainly not in a linear fashion for all particular freezing rate-final storage temperature combinations. Rancid flavor increases accelerated at a more rapid rate for +20°F stored roasts (Table 61). Sour flavor became less as storage time increased especially for roasts held at +20°F (Table 62). Thus, it would appear that rancid flavor replaces sour flavor as storage time proceeds.

Linear means for juiciness according to the overall project design are provided in Table 63. There were some indications of a slight reduction in juiciness with advancements in storage time and the use of +20°F storage. The process of freezing itself reduced juiciness scores (Table 64). Also, scores assigned following twelve months storage were lower than those assigned immediately following freezing.

After twelve months storage, nonabused product displayed lower juiciness scores than temperature abused product, but only for roasts frozen to 0°F in 24 hr (Table 65). Within nonabused product, roasts frozen to 0°F in 96 hr were rated as more juicy than those frozen to either 0°F in 24 or 72 hr. In a significant ( $P < .05$ ) interaction of storage time (immediately following freezing, twelve months) initial storage temperature, temperature abuse and freezing rate (Table 66). The major factor causing the interaction was the higher scores for juiciness given temperature abused samples frozen to 0°F in 24 hr, initially stored at

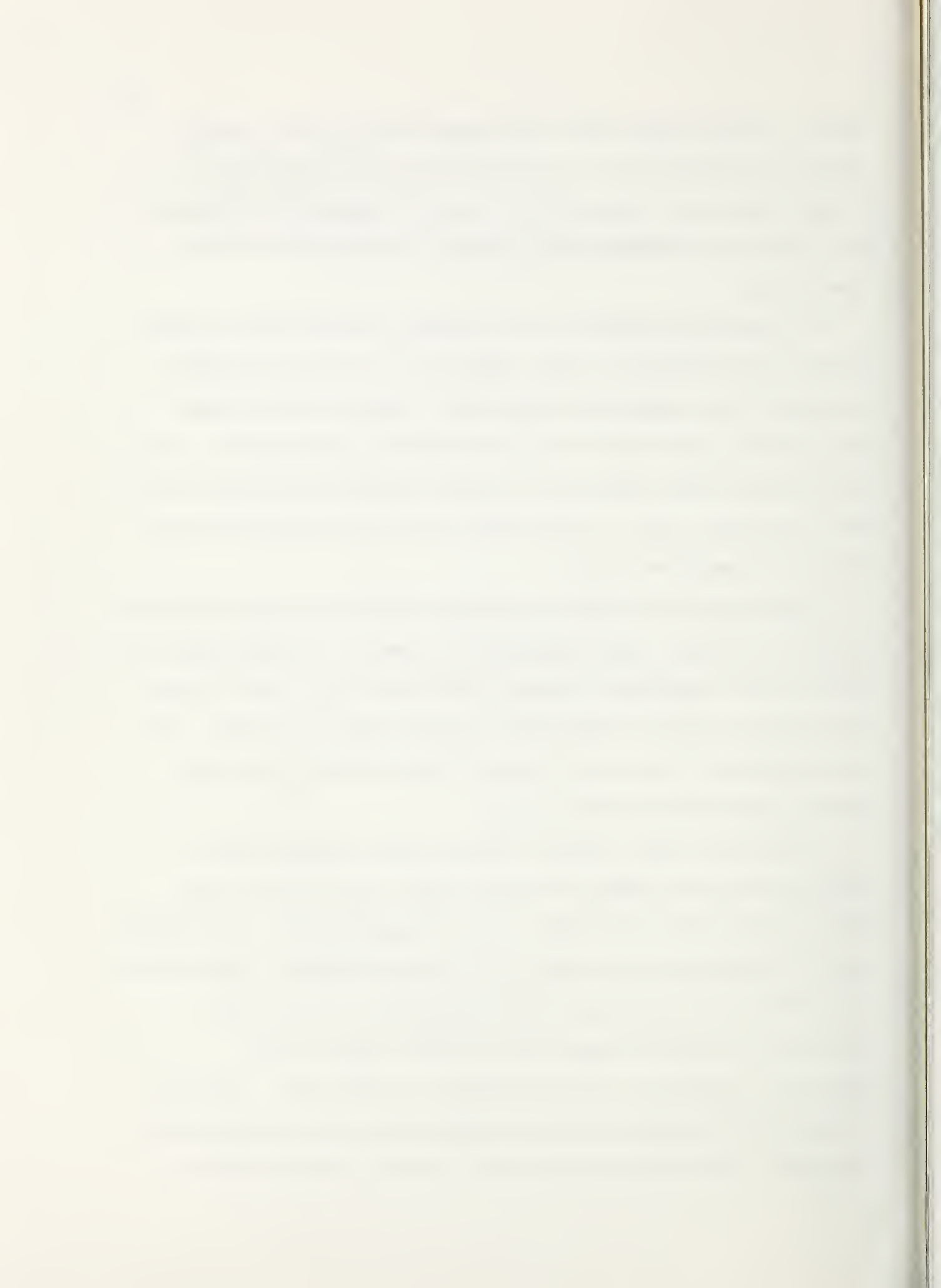


Table 60. Detectable flavor scores assigned to beef roasts according to final storage temperature following twelve months storage<sup>a</sup>

Detectable Flavors	Final storage temperature, °F		
	-10	0	20
Sour	30.0	33.09	24.62
Bitter	10.67	10.79	16.11
Metallic	24.67	25.18	23.40
Sweet	1.33	2.16	1.22
Rancid	10.0	12.23	21.28
Putrid	0.0	.72	.61
Salty	2.0	1.44	2.74
Other	21.33	14.39	10.03

Chi-square = 28.22,  $P < .013$

<sup>a</sup>Values are percentages of scores assigned within a final storage temperature.



Table 61. Incidence of rancid flavor in beef roasts throughout storage and according to freezing rate and final storage temperature<sup>a</sup>

Freezing Rate, hrs to 0°F	Final Storage Temperature, °F	Evaluation Time				
		Before freezing	Immediately after freezing, 1 day	6 mo	9 mo	12 mo
24	--	1.67	1.64			
	-10			3.33	4.00	18.60
	0			3.70	10.00	10.00
	+20			6.45	34.21	17.86
48	--	1.67	2.63			
	-10			6.45	12.50	2.70
	0			2.70	11.43	5.56
	+20			9.76	21.62	18.39
72	--	0.00	2.13			
	-10			12.90	20.00	13.89
	0			12.82	24.14	18.52
	+20			22.73	22.58	28.00
96	--	0.00	5.08			
	-10			0.00	5.71	2.94
	0			18.52	5.41	16.67
	+20			16.22	20.59	21.69

<sup>a</sup>Values are percent occurrence of rancid flavor among all flavors within a storage time-freezing rate-final storage temperature combination.

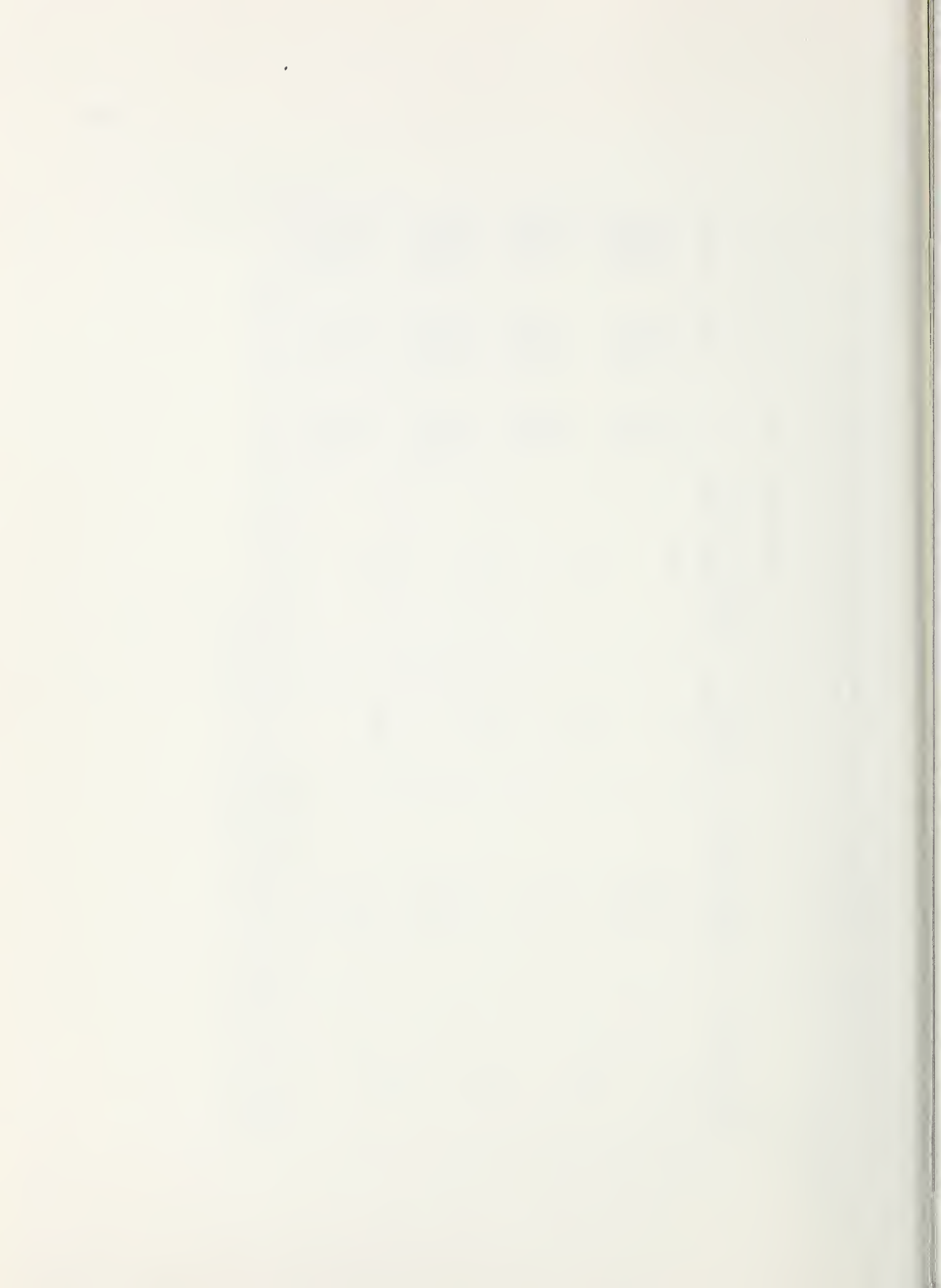


Table 62. Incidence of sour flavor in beef roasts throughout storage and according to freezing rate and final storage temperature<sup>a</sup>

Freezing Rate, hrs to 0°F	Final Storage Temperature, °F	Evaluation Time				
		Before freezing	Immediately after freezing, 1 day	6 mo	9 mo	12 mo
24	--	46.67	39.34			
	-10			33.33	44.00	23.26
	0			33.33	45.00	32.50
	+20			29.03	26.32	25.00
48	--	40.00	39.47			
	-10			19.35	33.33	24.32
	0			32.43	25.71	25.00
	+20			34.15	32.43	26.44
72	--	40.63	46.81			
	-10			32.26	33.33	30.56
	0			33.33	37.93	44.44
	+20			31.82	32.26	18.67
96	--	50.00	30.51			
	-10			32.00	25.71	44.12
	0			29.63	35.14	33.33
	+20			35.14	29.41	27.71

<sup>a</sup>Values are percent occurrence of sour flavor among all flavors within a storage time-freezing rate-final storage temperature combination.

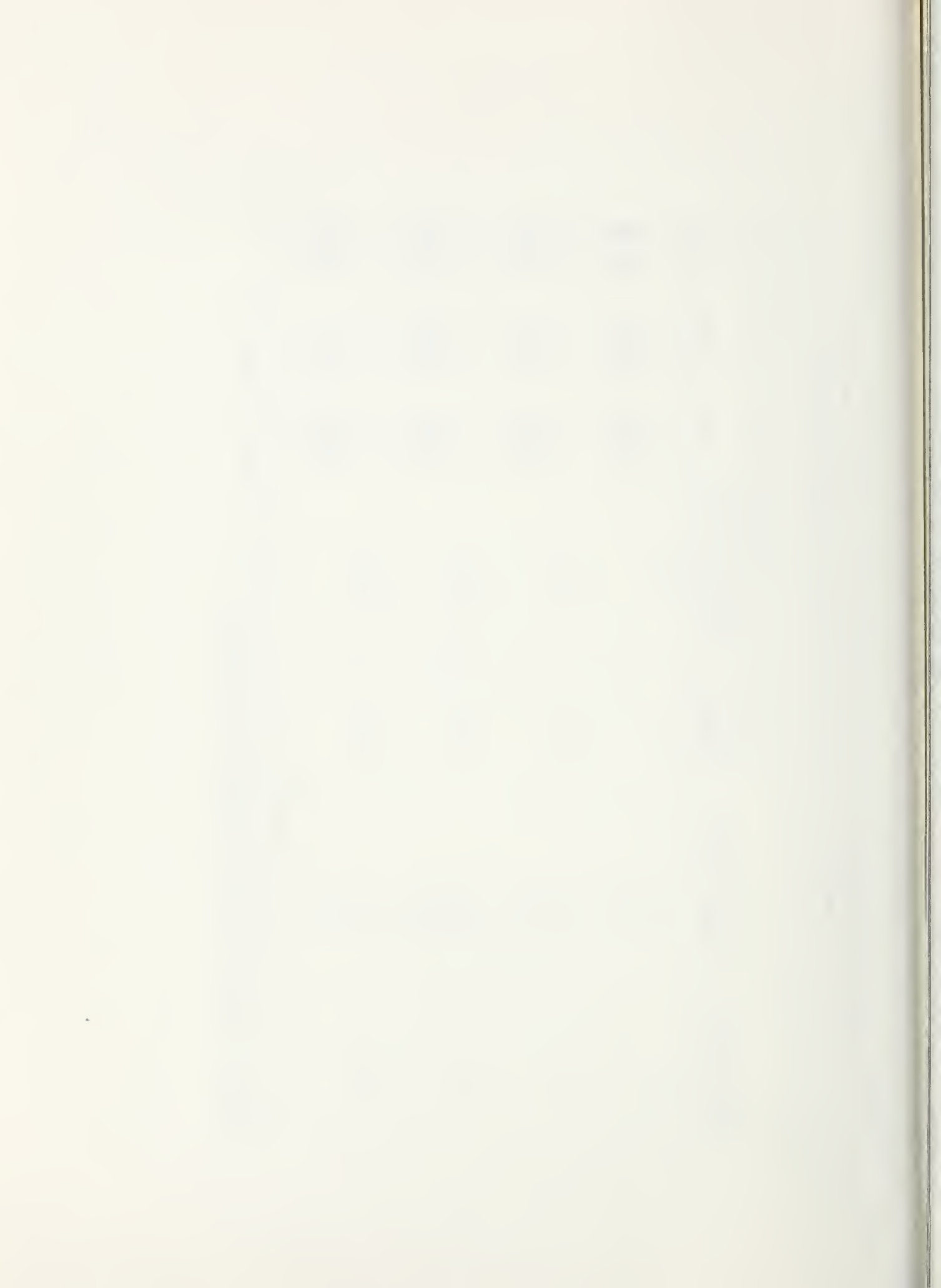




Table 63. General table illustrating sensory scores for juiciness in beef roasts throughout storage and according to final storage temperature and rate of freezing - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		5.16 ± .71	5.2 ± .79	5.22 ± .86	5.19 ± .94
Immediately after freezing, 1 day		4.58 ± 1.24	5.16 ± .96	5.04 ± 1.15	4.4 ± .71
6 months	-10T	4.71 ± .98	4.54 ± .91	4.99 ± .67	4.37 ± .98
	0T	4.6 ± .58	4.75 ± .81	5.19 ± .76	4.72 ± .91
	20T	4.57 ± .92	4.34 ± .85	4.66 ± 1.11	3.85 ± 1.01
9 months	-10T	4.35 ± .80	4.22 ± .95	4.24 ± .79	4.72 ± .87
	0T	4.70 ± 1.12	4.42 ± .88	4.53 ± 1.12	4.78 ± .77
	20T	4.77 ± 1.04	4.0 ± .95	4.53 ± .92	4.47 ± .76
12 months	-10T	4.94 ± .90	4.66 ± .68	4.68 ± .86	5.09 ± .67
	0T	4.77 ± .93	4.56 ± .81	4.66 ± .65	4.82 ± .68
	20T	4.83 ± .88	4.28 ± .60	4.58 ± .87	4.28 ± .81
	20N	3.7 ± 1.02	4.47 ± .79	3.62 ± .89	4.7 ± .68

<sup>a</sup>Mean ± S.D.; T = Temperature abused; N = Not temperature abused.



Table 64. Effect of various storage time comparisons on sensory scores for juiciness in roast beef

Evaluation time	
Before freezing	Immediately following freezing, 1 day
5.19 $\pm$ .12a	4.79 $\pm$ .12b
Immediately following freezing, 1 day	12 months
4.79 $\pm$ .08a	4.38 $\pm$ .08b

ab Means on the same line with different letters are different ( $P < .05$ ). Mean  $\pm$  S.E.

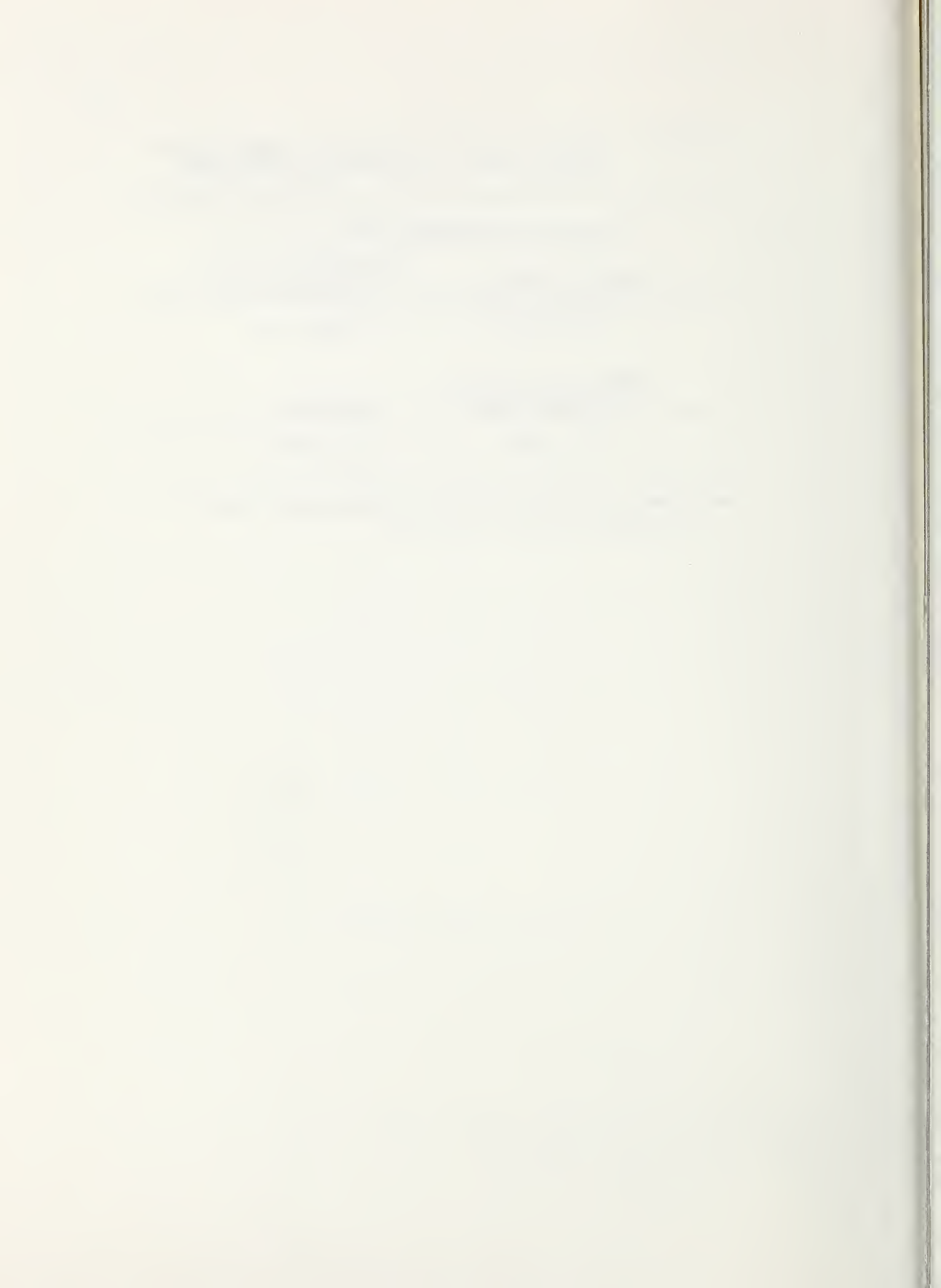


Table 65. Interaction effect of temperature abuse and rate of freezing on sensory scores for juiciness in beef roasts following twelve months storage

Freezing rate, hours to 0°F				
Temperature abuse	24	48	72	96
T	4.83 + .19a	4.28 + .19ab	4.58 + .19ab	4.28 + .19ab
N	3.7 + .19b	4.47 + .19ab	3.62 + .19b	4.7 + .19a

ab Any mean comparisons with the same letters are not different ( $P > .05$ ); Mean ± S.E.;  
T = Temperature abused; N = Not temperature abused.

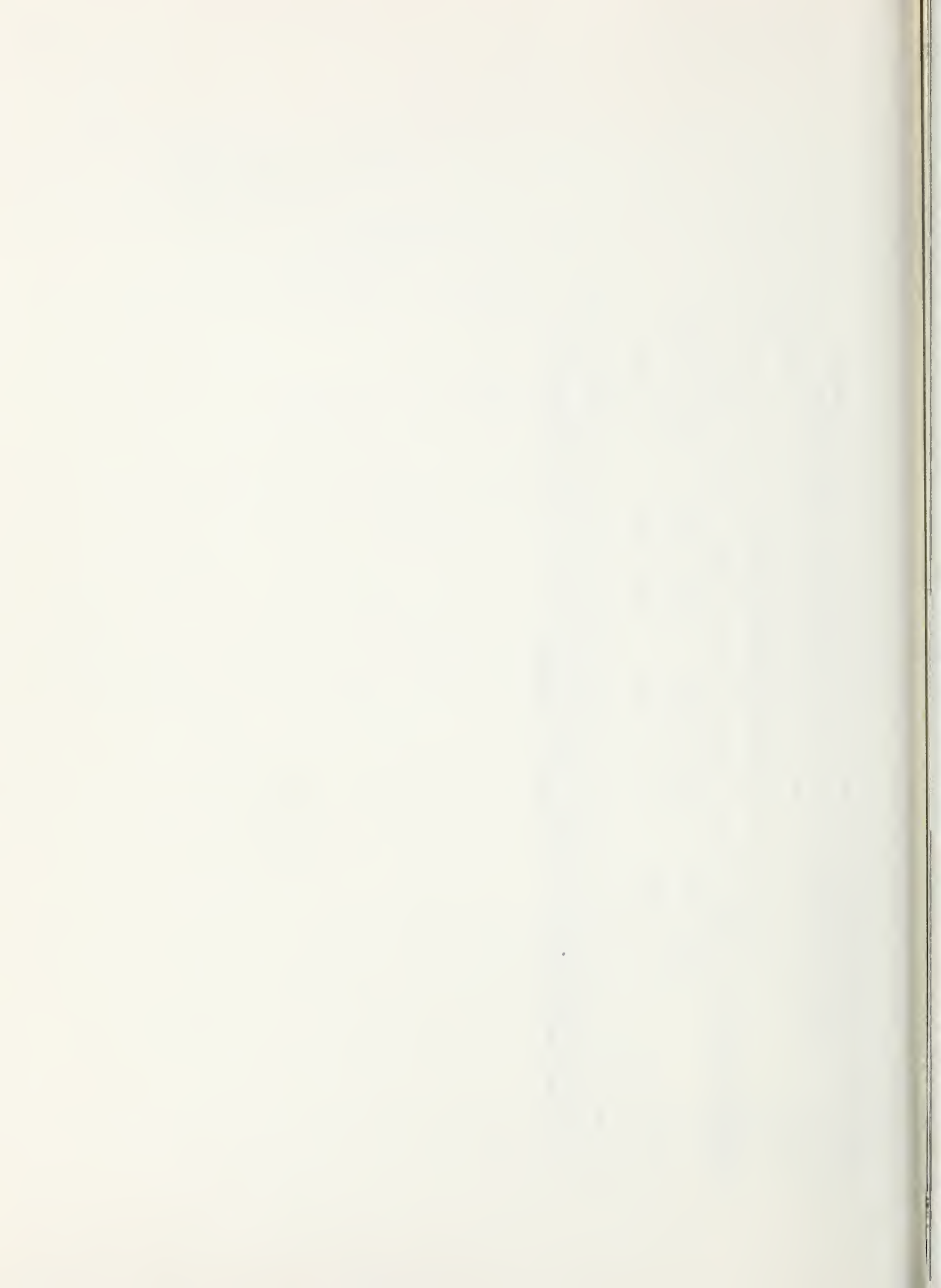
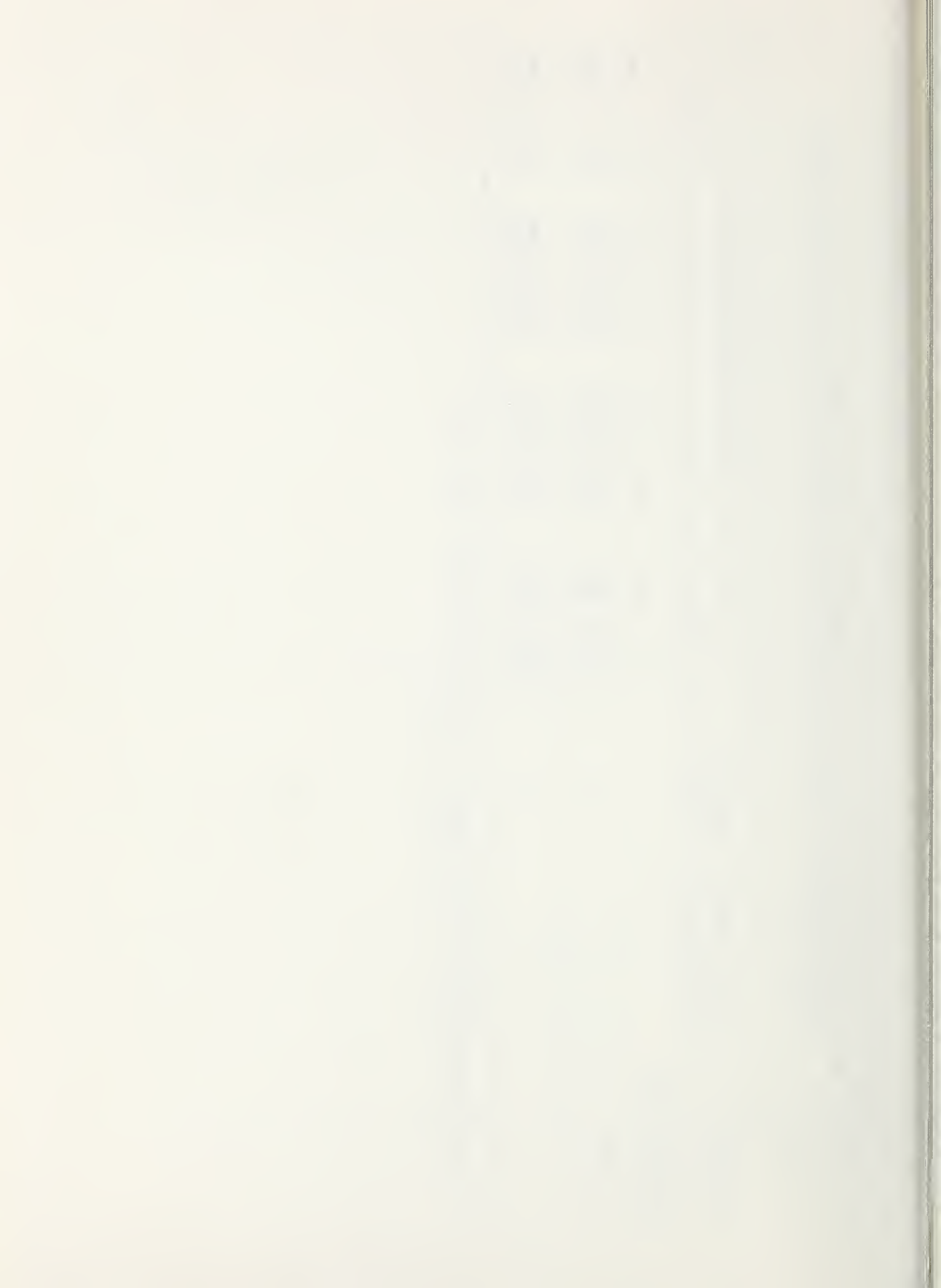


Table 66. Interaction effect of storage time (immediately following freezing, twelve months) initial storage temperature, temperature abuse and rate of freezing on sensory scores for juiciness in beef roasts

Evaluation time	Initial storage temperature, °F	Temperature abuse	Freezing rate, hours to °F			
			24	48	72	96
Immediately after freezing, 1 day						
12 months	-10		4.57 ± .16a	5.16 ± .16a	5.04 ± .16a	4.4 ± .16ab
		T	5.1 ± .42a	4.16 ± .42ab	4.25 ± .42ab	4.4 ± .42ab
	0	N	2.71 ± .42b	4.98 ± .42a	4.49 ± .42a	4.2 ± .42ab
		T	5.02 ± .42a	4.84 ± .42a	3.94 ± .42ab	4.36 ± .42ab
		N	4.24 ± .42ab	3.53 ± .42ab	3.74 ± .42ab	5.0 ± .42a

ab Any mean comparison with the same letter is not different ( $P > .05$ ). Mean ± S.E.  
T = temperature abused; N = not temperature abused.





-10°F and stored for twelve months compared to their nonabused counterpart under these conditions. Other comparisons between abused and nonabused roasts for juiciness in this interaction were nonsignificant ( $P>.05$ ).

For tenderness, the general overall means are displayed in Table 67. Storage at +20°F seemed to reduce the values. Increasing storage (immediately following storage against both nine and twelve months) resulted in lower sensory panel tenderness scores (Table 68). However, roasts stored for twelve months were scored as more tender than those held until nine months.

The slowest freezing rate (0°F in 96 hr) produced the least tender roasts following six months storage (Table 69). In an interaction of freezing rate and storage time (Table 70), the 0°F in 96 hr freezing rate produced less tender samples than 0°F in 24 at six months, but within 0°F in 24 hr, samples from nine-month-stored roasts were less tender than those stored six months. Freezing rate did not affect tenderness scores within nine-month-stored roasts.

A comparison of tenderness values obtained just after freezing vs those found in various samples from combinations of initial and final temperature at nine months are shown in Table 71. Only the roasts stored initially at 0°F and finally at +20°F underwent a tenderness reduction compared to that noted just after freezing. At twelve months, nonabused roasts initially stored at -10°F were lower in tenderness than roast samples evaluated just after freezing (Table 72).

General linear means and standard deviations for connective tissue amount are presented in Table 73. It would not be expected that connective tissue amount would be greatly affected by the factors evaluated in this study. Scores for connective tissue revealed slightly less at nine months



Table 67. General table illustrating sensory scores for tenderness in beef roasts throughout storage according to final storage temperature and rate of freezing - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		6.2 ± .70	6.59 ± .72	6.54 ± .57	6.59 ± .77
Immediately after freezing, 1 day		6.66 ± .90	6.22 ± .99	6.25 ± .95	6.07 ± .83
6 months	-10T	6.43 ± 1.18	5.93 ± 1.13	6.51 ± .92	5.26 ± 1.12
	0T	6.25 ± .94	5.87 ± 1.15	6.12 ± .96	5.19 ± 1.0
	20T	6.15 ± .83	5.82 ± .78	5.06 ± 1.15	4.7 ± .97
9 months	-10T	5.22 ± 1.11	5.1 ± .88	5.87 ± 1.36	5.75 ± 1.24
	0T	5.32 ± 1.04	5.67 ± .94	5.72 ± 1.32	5.31 ± 1.18
	20T	5.42 ± 1.21	5.17 ± .80	5.36 ± .79	5.34 ± .98
12 months	-10T	6.0 ± .94	6.06 ± .73	5.69 ± 1.24	6.21 ± .85
	0T	5.72 ± .87	5.62 ± .90	5.94 ± 1.06	5.28 ± 1.2
	20T	5.99 ± .91	5.87 ± .76	5.41 ± 1.13	4.86 ± 1.08
	20N	5.22 ± 1.19	5.95 ± .67	4.77 ± .71	5.32 ± .77

<sup>a</sup>Mean ± S.D.; T = Temperature abused; N = Not temperature abused.

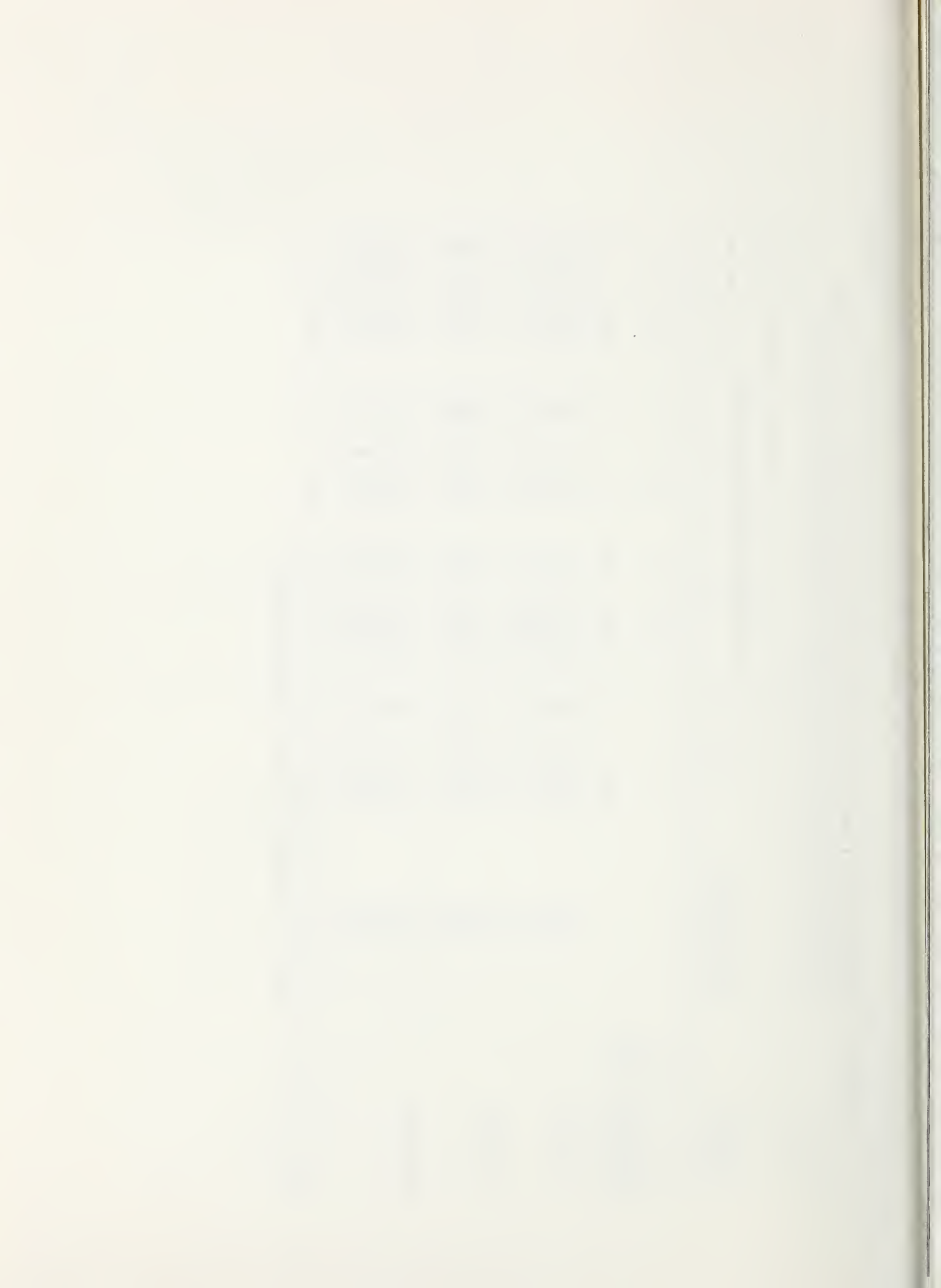


Table 68. Effect of various storage time comparisons on sensory scores for tenderness in beef roasts

Storage Time Comparison	
Immediately following freezing, 1 day	9 months
6.19 $\pm$ .17a	5.44 $\pm$ .17b
Immediately following freezing, 1 day <sup>c</sup>	12 months <sup>c</sup>
6.19 $\pm$ .19a	5.72 $\pm$ .19b
Immediately following freezing, 1 day	12 months <sup>d</sup>
6.30 $\pm$ .17a	5.43 $\pm$ .17b
9 months	12 months
5.44 $\pm$ .084b	5.72 $\pm$ .084a

ab Difference between means on the same line is significant ( $P < .05$ ). Mean  $\pm$  S.E.

<sup>c</sup>Includes only temperature abused product.

<sup>d</sup>Includes only +20°F final storage temperature product.

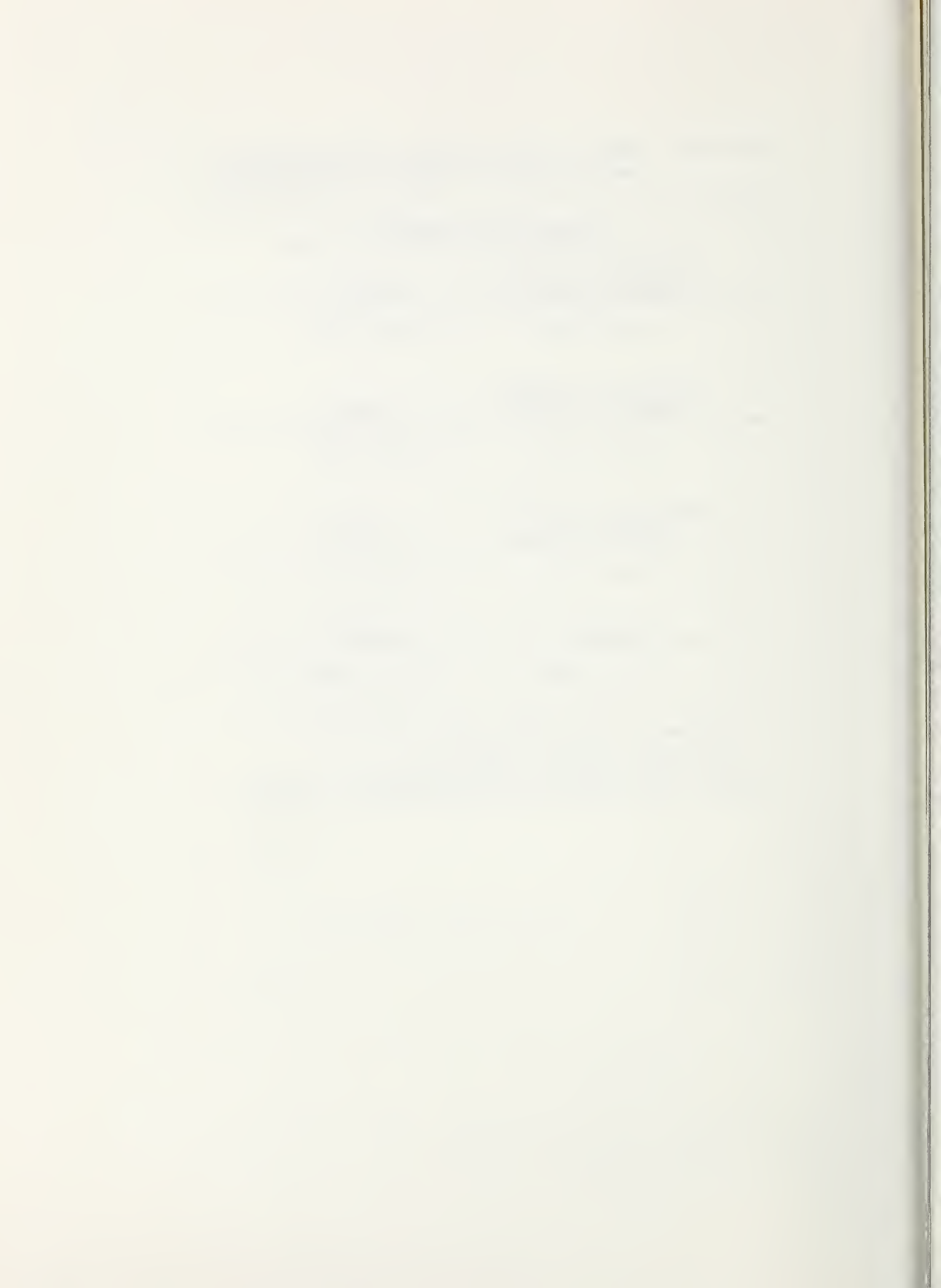


Table 69. Effect of freezing rate on sensory scores for tenderness in beef roasts following six months storage

Freezing rate, hours to 0°F			
24	48	72	96
6.28 $\pm$ .2a	5.88 $\pm$ .2a	5.90 $\pm$ .2a	5.05 $\pm$ .2b

ab Means on the same line with different letters are different ( $P < .05$ ).  
Mean  $\pm$  S.E.





Table 70. Interaction effect of storage time (six, nine months) and rate of freezing on sensory scores for tenderness in beef roasts

Evaluation time, months	Freezing rate, hours to °F			
	24	48	72	96
6	6.28 + .18a	5.88 + .18abc	5.9 + .18ab	5.05 + .18c
9	5.32 + .18bc	5.32 + .18bc	5.65 + .18abc	5.47 + .18abc

abc Any mean comparisons with the same letters are not different ( $P > .05$ ). Mean + S.E.

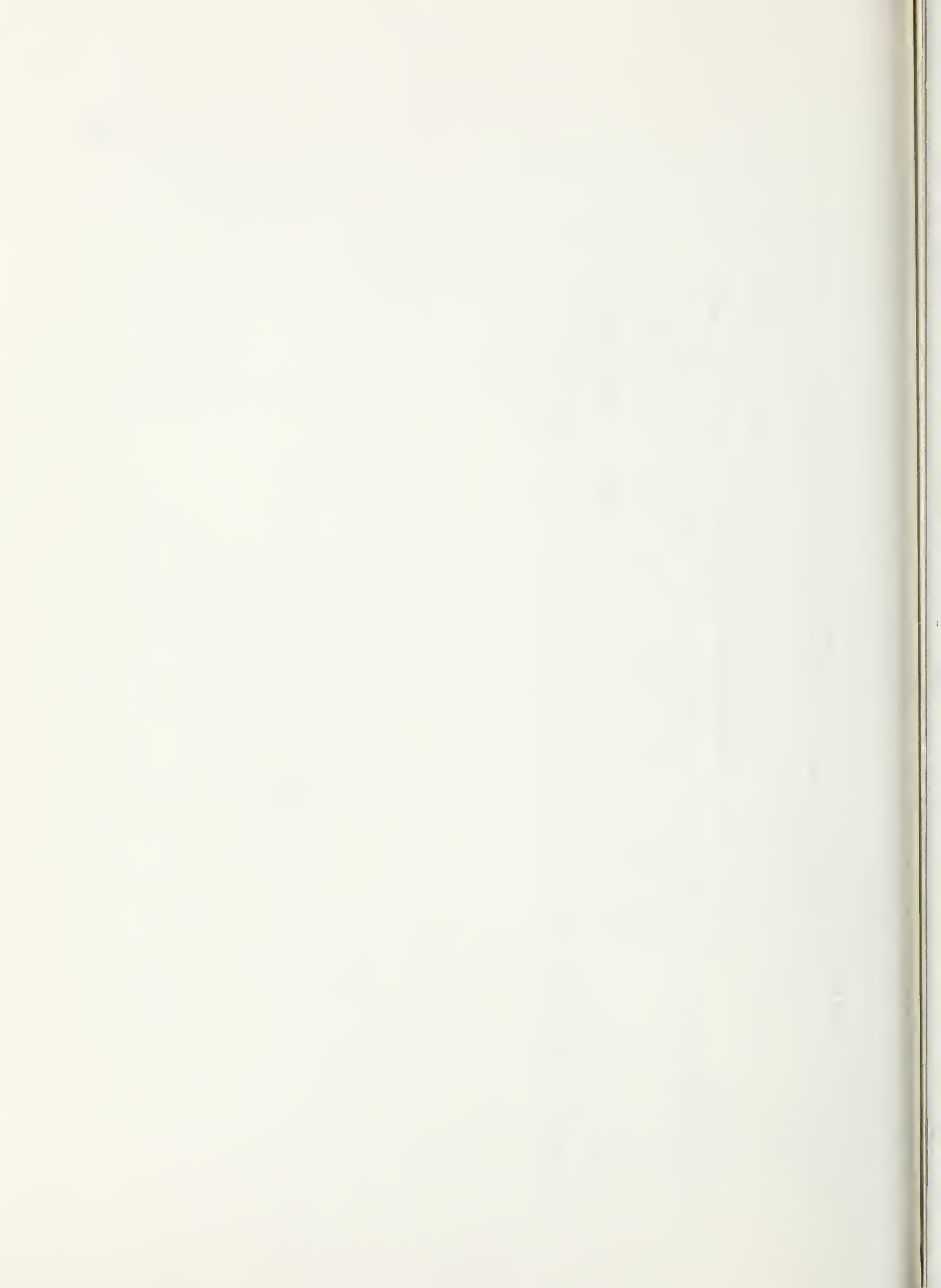


Table 71. Effect of storage time (immediately following freezing, nine months) on sensory scores for tenderness in beef roasts

		9 months storage			
		Initial storage temperature, °F =		0	
		-10		0	
		Final storage temperature, °F =		-10	
		-10		20	
		0		-10	
		5.31 ± .26ab		5.29 ± .26ab	
		5.68 ± .26ab		5.44 ± .26ab	
		6.19 ± .15a		5.71 ± .26ab	
				5.21 ± .26b	
				20	

ab Means on the same line with the same letters are not different ( $P > .05$ ); Mean ± S.E.



Table 72. Effect of storage time (immediately following freezing, twelve months) on sensory scores for tenderness in beef roasts

Immediately following freezing, 1 day	12 Months Storage		
	Temperature Abuse =	T	N
Initial storage temperature, °F =	-10	0	-10
6.3 + .12a	5.71 + .33ab	5.57 + .33ab	5.08 + .33b
			5.35 + .33ab

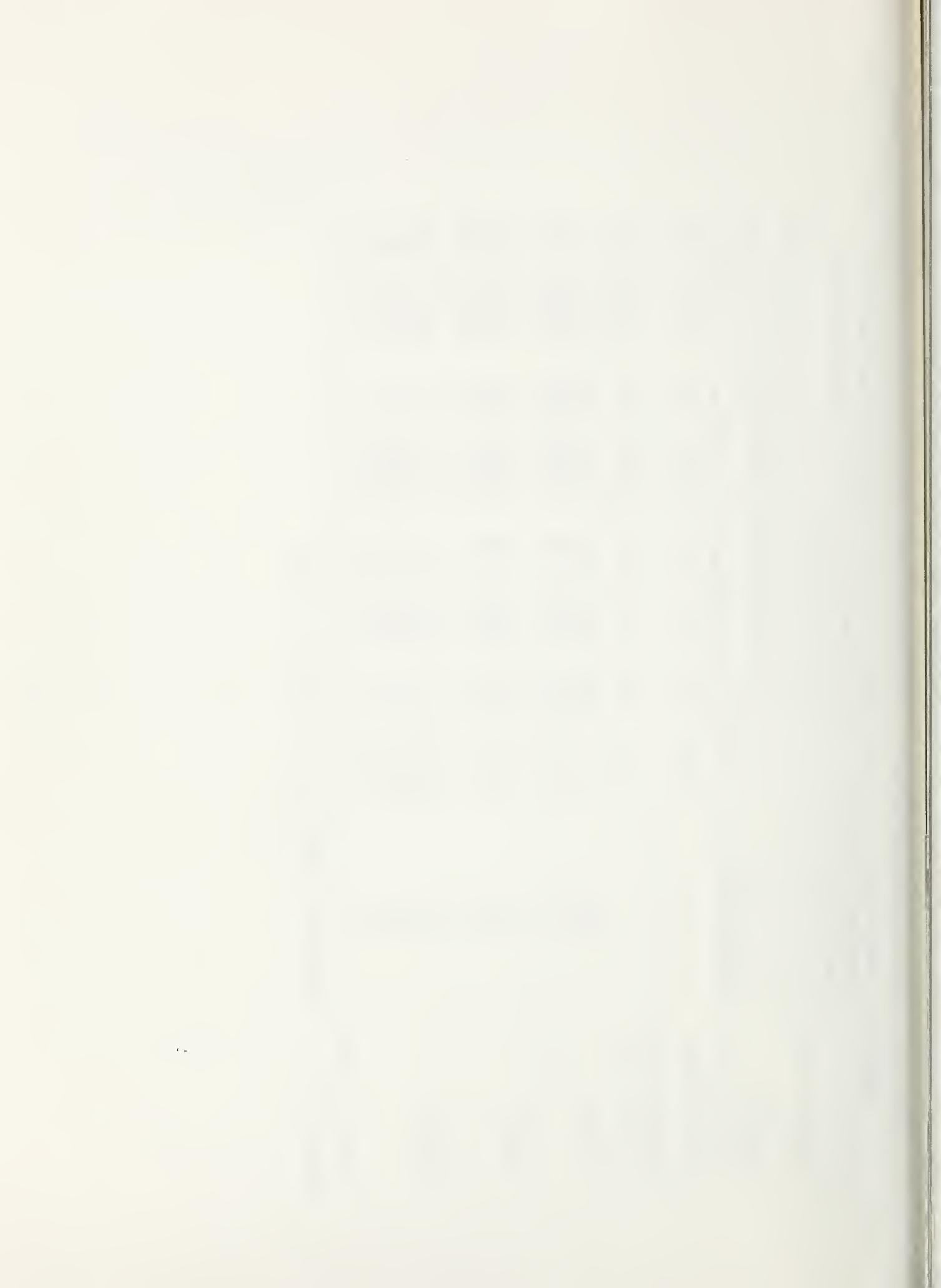
ab Means on the same line with the same letters are not different ( $P > .05$ ). Mean + S.E.  
 Includes only +20°F final storage temperature.  
 T = temperature abused, N = not temperature abused.



Table 73. General table illustrating sensory scores for connective tissue amount in beef roasts throughout storage and according to final storage temperature and rate of freezing - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		7.36 ± .54	7.37 ± .64	7.59 ± .48	7.25 ± .65
Immediately after freezing, 1 day		7.57 ± .47	7.1 ± .78	7.44 ± .61	7.46 ± .66
6 months	-10T	7.5 ± .54	6.94 ± .80	7.41 ± .59	7.22 ± .72
	0T	7.5 ± .54	7.29 ± .59	7.19 ± .62	6.95 ± .63
	20T	7.4 ± .60	7.31 ± .52	7.18 ± .67	7.21 ± .72
9 months	-10T	7.57 ± .44	7.17 ± .57	7.72 ± .35	7.37 ± .78
	0T	7.22 ± .64	7.62 ± .53	7.32 ± .61	7.06 ± .40
	20T	7.22 ± .64	7.5 ± .49	7.07 ± .78	6.94 ± .48
12 months	-10T	6.65 ± 1.15	7.47 ± .56	7.21 ± .71	7.69 ± .43
	0T	7.07 ± .52	7.37 ± .46	7.25 ± .84	7.36 ± .59
	20T	6.94 ± .88	7.37 ± .59	6.98 ± .81	7.22 ± .64
	20N	7.45 ± .63	7.55 ± .43	7.17 ± .77	7.35 ± .54

<sup>a</sup>Mean ± S.D.; T = Temperature abused; N = Not temperature abused.





compared to that found right after freezing (Table 74). An interaction of storage time, initial storage temperature, final storage temperature, and freezing rate is shown in Table 74, but the differences follow no logical trend. The same can be said of the interactions depicted in Tables 75 and 76.

The next section deals with results obtained from Instron measurements taken on roast samples. Results pertaining to samples evaluated as cores are given first followed by results on roast beef slices. Table 77 provides overall means and standard deviations for Instron peak load values in kg according to storage time, final storage temperature and freezing rate. Not too many trends can be noted, except for the higher values for roasts frozen to 0°F in 72 hr. Actually, roasts for both the 0°F in 72 and 96 hr freezing rates produced higher peak load values before freezing than roasts used for the 0°F in 48 hr (Table 78). After 9 months, roasts originally frozen to 0°F in 72 hr had higher values than the other three rates (Table 79).

With the exception of roasts frozen to 0°F in 96 hr, initial storage at 0°F produced higher peak load values than initial storage at -10°F (Table 80). Advances in storage time (six, nine months) produced a toughening in roast cores, as measured by peak load, as compared to immediately following freezing (Table 81). Following six months of storage, peak load values of cores from roasts initially stored at -10°F did not differ from values obtained immediately following freezing while values for roasts stored initially at 0°F were higher (Table 82). This was true regardless of final storage temperature.

After nine months of storage, peak load values for roasts frozen to 0°F in 72 hr and placed in -10°F final storage exceeded values for all



Table 74. Interaction effect of storage time (immediately following freezing, nine months) initial storage temperature, final storage temperature and rate of freezing on sensory scores for connective tissue amount in beef roasts

Evaluation time	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to °F			
			24	48	72	96
Immediately after freezing, 1 day			7.52 ± .14ab	7.0 ± .14ab	7.4 ± .14ab	7.6 ± .14ab
9 months	-10	-10	7.32 ± .25ab	6.95 ± .25ab	7.79 ± .25ab	6.89 ± .25ab
		0	6.98 ± .25ab	7.1 ± .25ab	7.05 ± .25ab	6.95 ± .25ab
		20	6.92 ± .25ab	7.40 ± .25ab	7.15 ± .25ab	6.64 ± .25b
	0	-10	7.82 ± .25a	7.40 ± .25ab	7.65 ± .25ab	7.86 ± .25a
		0	7.47 ± .25ab	7.90 ± .25a	7.60 ± .25ab	7.17 ± .25ab
		20	7.52 ± .25ab	7.60 ± .25ab	7.00 ± .25ab	7.24 ± .25ab

ab Any mean comparison with the same letters is not different ( $P > .05$ ). Mean ± S.D.

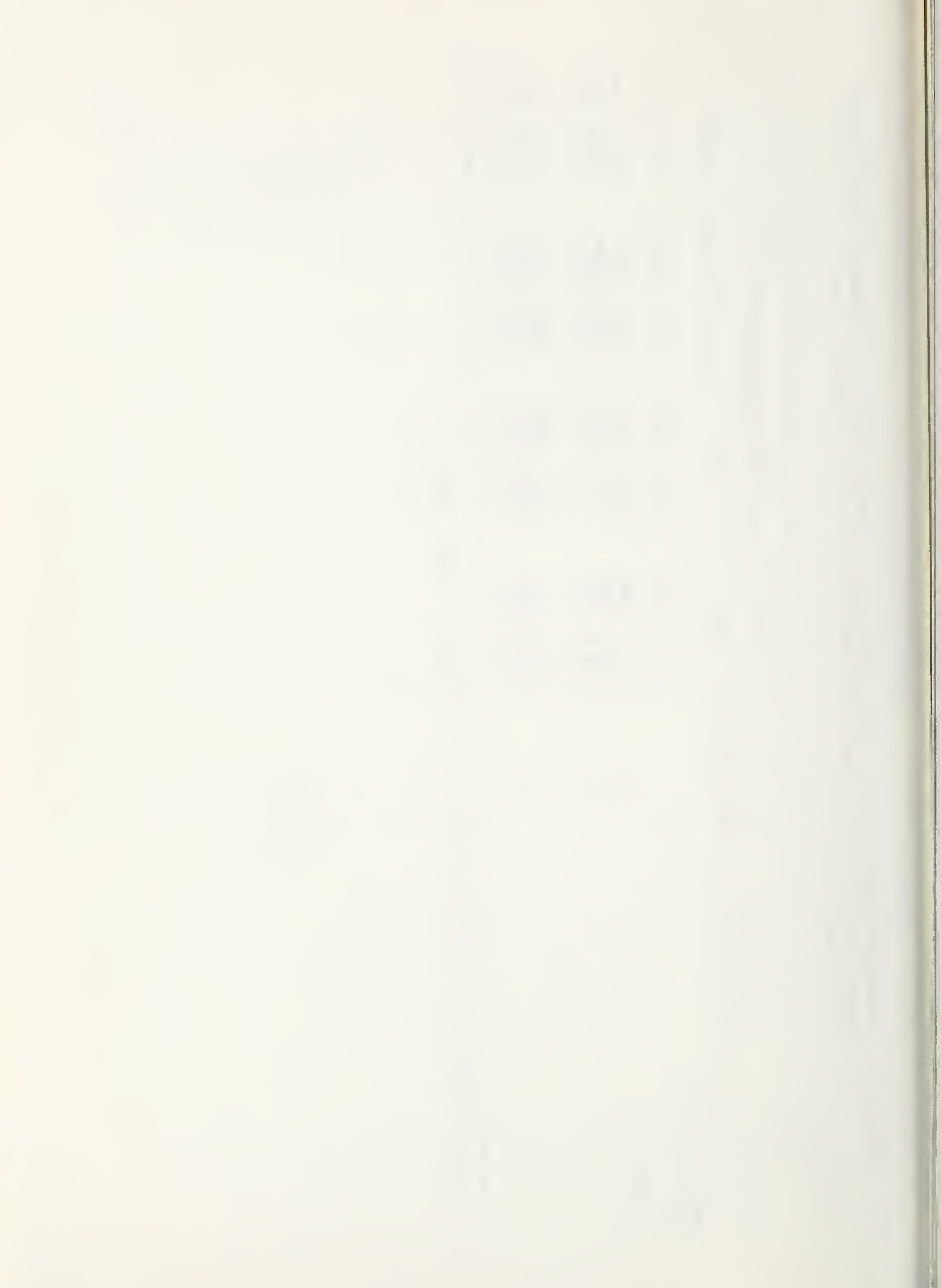


Table 75. Interaction effect of initial storage temperature, final storage temperature and rate of freezing on sensory scores for connective tissue amount in beef roasts following twelve months storage

Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
-10	-10	7.62 ± .25a	7.31 ± .25a	6.85 ± .25ab	7.72 ± .25a
	0	7.27 ± .25a	7.25 ± .25a	7.69 ± .25a	7.32 ± .25a
	20	7.09 ± .25ab	7.12 ± .25ab	6.79 ± .25ab	7.05 ± .25ab
0	-10	5.67 ± .25b	7.62 ± .25a	7.56 ± .25a	7.65 ± .25a
	0	6.87 ± .25ab	7.5 ± .25a	6.81 ± .25ab	7.4 ± .25a
	20	6.78 ± .25ab	7.62 ± .25a	7.17 ± .25ab	7.39 ± .25a

ab Any mean comparison with the same letters is not different ( $P > .05$ ); Mean ± S.E.



Table 76. Interaction effect of storage time (nine, twelve months) initial storage temperature, final storage temperature, and rate of freezing on sensory scores for connective amount in beef roasts

Evaluation time, months	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to °F			
			24	48	72	96
9	-10	-10	7.5 + .27a	7.2 + .27ab	7.79 + .27a	6.94 + .27ab
		0	7.15 + .27ab	7.35 + .27ab	7.05 + .27ab	7.0 + .27ab
		20	7.1 + .27ab	7.65 + .27a	7.15 + .27ab	6.69 + .27ab
12	0	-10	7.65 + .27ab	7.15 + .27ab	7.65 + .27a	7.81 + .27a
		0	7.3 + .27ab	7.9 + .27a	7.6 + .27a	7.12 + .27ab
		20	7.35 + .27ab	7.35 + .27ab	7.0 + .27ab	7.19 + .27ab
	-10	-10	7.62 + .27a	7.31 + .27ab	6.85 + .27ab	7.72 + .27a
		0	7.27 + .27ab	7.25 + .27ab	7.69 + .27a	7.32 + .27ab
		20	7.09 + .27ab	7.12 + .27ab	6.79 + .27ab	7.05 + .27ab
	0	-10	5.67 + .27b	7.62 + .27a	7.56 + .27a	7.65 + .27a
		0	6.87 + .27ab	7.5 + .27a	6.81 + .27ab	7.4 + .27a
		20	6.78 + .27ab	7.62 + .27a	7.17 + .27ab	7.39 + .27ab

ab Any mean comparison with the same letters is not different ( $P>.05$ ); Mean + S.E.

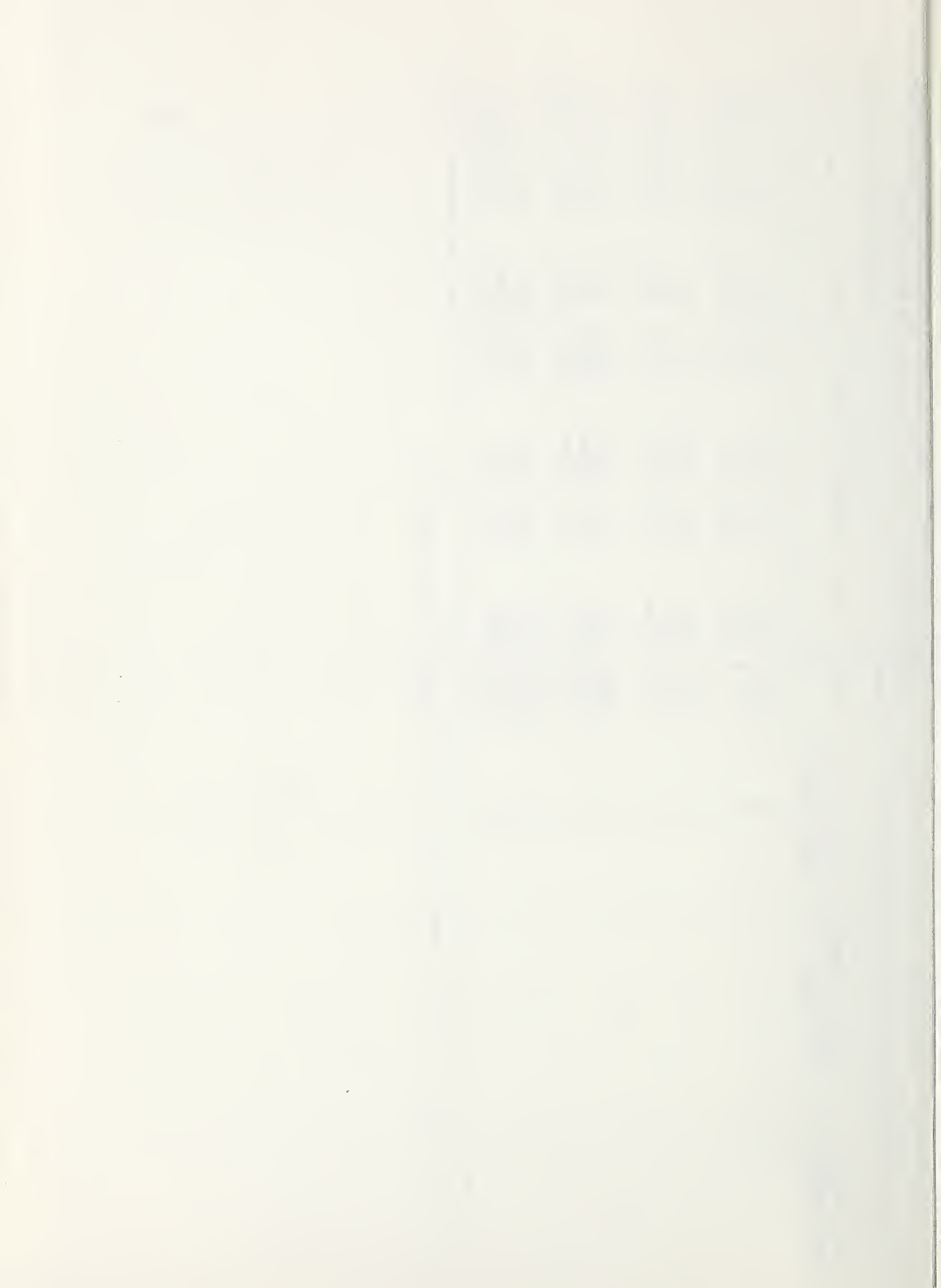




Table 77. General table illustrating Instron peak load values for roast beef cores throughout storage times and according to final storage temperature and rate of freezing - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		2.87 ± .75	2.57 ± .64	3.69 ± .76	3.66 ± 1.15
Immediately after freezing, 1 day		3.01 ± .73	3.43 ± .77	3.31 ± .92	3.64 ± .73
6 months	-10T	3.29 ± .53	3.52 ± .60	4.01 ± 1.21	3.44 ± .68
	0T	3.78 ± .71	3.44 ± .68	4.16 ± 1.34	3.77 ± 1.17
	20T	3.57 ± .74	3.50 ± .91	4.34 ± 1.41	3.88 ± .69
9 months	-10T	3.29 ± .72	3.52 ± 1.20	5.34 ± .87	3.14 ± .71
	0T	4.09 ± .77	3.69 ± .72	4.66 ± 1.07	3.57 ± .98
	20T	3.84 ± .95	3.16 ± .59	5.03 ± 1.03	3.68 ± .61
12 months	-10T	3.37 ± .45	3.33 ± .63	3.29 ± .62	4.00 ± .94
	0T	3.46 ± .62	3.07 ± .60	3.28 ± .83	3.56 ± .72
	20T	3.43 ± .91	3.25 ± .67	4.06 ± .66	4.27 ± .96
	20N	5.77 ± .99	3.92 ± .79	3.64 ± .87	3.47 ± .84

Mean ± S.D. T = temperature abused. N = not temperature abused.



Table 78 . Interaction effect of storage time (just before freezing, immediately following freezing) and rate of freezing on Instron peak load values for roast beef cores

Evaluation time	Freezing rate, hours to 0°F			
	24	48	72	96
Before freezing	2.87 $\pm$ .21ab	2.57 $\pm$ .21b	3.69 $\pm$ .21a	3.66 $\pm$ .21a
Immediately after freezing, 1 day	3.01 $\pm$ .21ab	3.43 $\pm$ .21ab	3.31 $\pm$ .21ab	3.64 $\pm$ .21a

ab Any mean comparisons with the same letters are not different ( $P > .05$ ).  
Mean  $\pm$  S.E.



Table 79. Effect of freezing rate on Instron peakload values for roast beef cores at various storage times

Evaluation time	Freezing rate, hours to 0°F			
	24	48	72	96
Immediately following freezing, 1 day	2.87 $\pm$ .25ab	2.57 $\pm$ .25b	3.69 $\pm$ .25a	3.66 $\pm$ .25a
9 months	3.74 $\pm$ .22b	3.46 $\pm$ .22b	5.01 $\pm$ .22a	3.46 $\pm$ .22b

ab Means on the same line with different letters are different ( $P > .05$ ).  
 Mean  $\pm$  S.E.



Table 80. Interaction effect of initial storage temperature and rate of freezing on Instron peak load values for roast beef cores following six months of storage

Initial storage temperature, °F	Freezing rate, hours to 0°F			
	24	48	72	96
-10	3.36 ± .20c	3.30 ± .20c	3.16 ± .20c	3.93 ± .20b
0	3.74 ± .20b	3.67 ± .20b	5.19 ± .20a	3.47 ± .20bc

abc Any mean comparison with different letters is different (P<.05).





Table 81. Effect of various storage time comparisons on Instron peakload values for roast beef cores

<u>Evaluation time</u>	
<u>Immediately following freezing, 1 day</u>	<u>6 months</u>
3.30 $\pm$ .13	3.73 $\pm$ .13
<u>Immediately following freezing, 1 day</u>	<u>9 months</u>
3.30 $\pm$ .12b	3.92 $\pm$ .12a

ab Differences between means significant ( $P < .05$ ). Mean  $\pm$  S.E.



Table 82 . Effect of storage time (immediately following freezing, six months) on Instron peak load values for roast beef cores

		6 Months Evaluation Time			
Immediately after freezing, 1 day	Initial storage temperature, °F =	-10		0	
	Final storage temperature, °F	-10	20	-10	20
3.30 ± .11b		3.02 ± .20b	3.43 ± .20b	3.38 ± .20b	4.11 ± .20a
				4.15 ± .20a	4.26 ± .20a

ab Means on the same line with different letters are different (P<.05). Mean ± S.E.



final temperature-freezing rate combinations outside 0°F in 72 hr (Table 83). For roasts stored at +20°F, peak load values were higher for the 0°F in 72 hr rate compared to the other three rates, while within 0°F final storage, no differences ( $P>.05$ ) were found attributable to freezing rate. The major factor causing the significant ( $P<.05$ ) interaction of storage time (immediately following freezing, nine months), initial and final storage temperature and freezing rate appears to be the high peak load values found for roasts frozen to 0°F in 72 hr and initially stored at -10°F compared especially to those stored initially at -10°F, but frozen to 0°F in either 48 or 72 hr (Table 84). Differences resulting in an interaction of storage time (six, nine months) initial storage temperature and freezing rate appear again to be the higher peak loads for roasts frozen to 0°F in 72 hr, except for six-month-stored roasts initially held at -10°F and the increase in peak load between six and nine months in roasts initially stored at 0°F only for those frozen to 0°F in 48 hr (Table 85).

Peak load values were higher at twelve months for cores from roasts initially stored at 0°F and finally stored at +20°F compared to roasts stored initially and finally at 0°F (Table 86). Also at twelve months, temperature abuse produced a reduction in peak load for roasts frozen to 0°F in 24 hr, but the opposite effect for roasts frozen to 0°F in 96 hr (Table 87). Only roasts initially stored at +20°F increased in peak load following twelve months compared to that found immediately after freezing (Table 88). An interaction of storage time (immediately following freezing, twelve months), initial storage temperature, temperature abuse within +20°F final temperature and freezing rate is presented in Table 89. Compared to peak load values noted right after freezing, those found for nonabused roasts frozen to 0°F in 24 hr were higher regardless of initial



Table 83. Interaction effect of final storage temperature and rate of freezing on Instron peak load values for roast beef cores following nine months storage

Final storage temperature, °F	Freezing rate, hours to 0°F			
	24	48	72	96
-10	3.29 ± .22d	3.52 ± .22cd	5.34 ± .22a	3.14 ± .22d
0	4.09 ± .22bcd	3.69 ± .22cd	4.66 ± .22abc	3.57 ± .22cd
20	3.84 ± .22cd	3.16 ± .22d	5.03 ± .22ab	3.68 ± .22cd

abcd Any mean comparisons with different letters are different ( $P < .05$ ).  
Mean ± S.E.





Table 84. Interaction effect of storage time (Immediately following freezing, nine months), initial storage temperature, final storage temperature and rate of freezing on Instron peak load values for roast beef cores

Evaluation time	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F			
			24	48	72	96
Immediately after freezing, 1 day			3.00 ± .21b	3.29 ± .21b	3.06 ± .21b	3.84 ± .21ab
9 months	-10	-10	2.75 ± .37b	2.82 ± .37b	5.87 ± .37a	2.19 ± .37b
		0	4.31 ± .37ab	3.68 ± .37b	4.85 ± .37a	2.76 ± .37b
		20	3.24 ± .37b	2.96 ± .37b	5.37 ± .37a	3.22 ± .37b
	0	-10	3.83 ± .37ab	4.22 ± .37ab	4.82 ± .37a	4.08 ± .37ab
		0	3.88 ± .37ab	3.70 ± .37b	4.48 ± .37a	4.38 ± .37a
		20	4.44 ± .37a	3.37 ± .37b	4.69 ± .37a	4.13 ± .37ab

ab Any mean comparisons with the same letters are not different ( $P > .05$ ). Mean ± S.E.



Table 85 . Interaction effect of storage time (six, nine months), initial storage temperature and rate of freezing on Instron peak load values for roast beef cores

Evaluation time	Initial storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
6	-10	3.36 $\pm$ .18c	3.30 $\pm$ .18c	3.16 $\pm$ .18c	3.93 $\pm$ .18bc
9	-10	3.69 $\pm$ .18c	3.11 $\pm$ .18c	5.24 $\pm$ .18a	3.27 $\pm$ .18c
6	0	3.74 $\pm$ .18c	3.67 $\pm$ .18c	5.19 $\pm$ .18a	3.47 $\pm$ .18c
9	0	3.79 $\pm$ .18c	3.81 $\pm$ .18b	4.78 $\pm$ .18ab	3.65 $\pm$ .18c

abc Any mean comparisons with the same letters are not different ( $P > .05$ ).  
Mean  $\pm$  S.E.



Table 86. Interaction effect of final storage temperature and initial storage temperature on Instron peak load values for roast beef cores following twelve months storage

Final storage temperature, °F	Initial storage temperature, °F	
	-10	0
-10	3.37 $\pm$ .15ab	3.63 $\pm$ .15ab
0	3.60 $\pm$ .15ab	3.09 $\pm$ .15b
20	3.59 $\pm$ .15ab	3.92 $\pm$ .15a

ab Any mean comparisons with the same letters are different (P<.05). Mean  $\pm$  S.E.

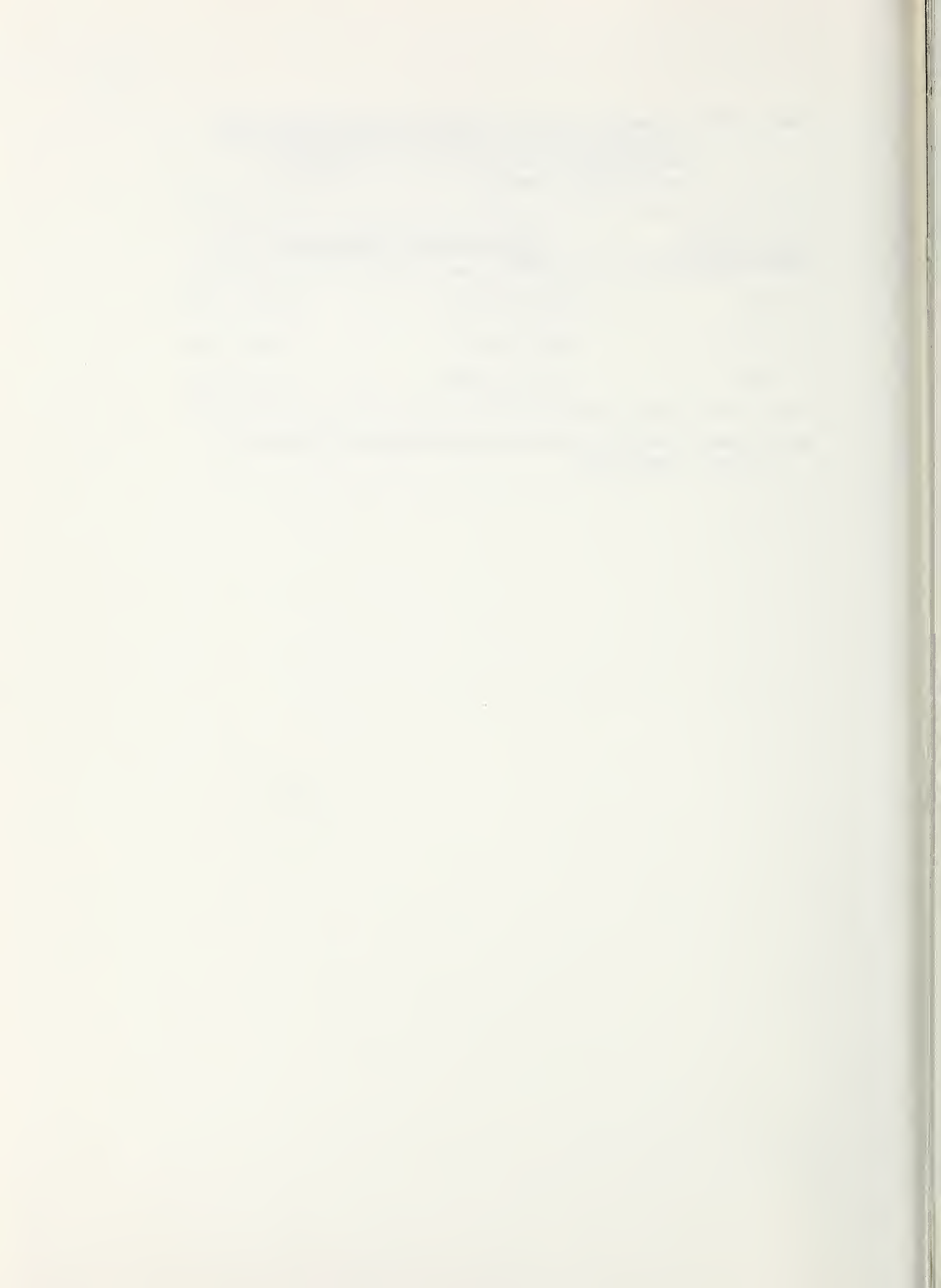


Table 87 . Interaction effect of temperature abuse and rate of freezing on Instron peak load values for roast beef cores following twelve months

Temperature abuse	Freezing rate, hours to 0°F			
	24	48	72	96
T	3.43 $\pm$ .32c	3.25 $\pm$ .32c	4.06 $\pm$ .32bc	4.27 $\pm$ .32ab
N	5.77 $\pm$ .32a	3.92 $\pm$ .32bc	3.64 $\pm$ .32c	3.47 $\pm$ .32c

abc Any mean comparisons with different letters are different ( $P < .05$ ).

Mean  $\pm$  S.E. T = temperature abused. N = not temperature abused.





Table 88. Effect of storage time (immediately following freezing, twelve months) on Instron peak load values for roast beef cores

		12 months storage			
Immediately following freezing, 1 day	Initial storage temperature, °F =	-10			
	Final storage temperature, °F =	-10	0	20	-10
3.30 ± .11b		3.21 ± .19b	3.44 ± .19ab	3.43 ± .19ab	3.79 ± .19ab
				3.25 ± .19b	4.08 ± .19a

ab Means on the same line with the same letters are not different ( $P > .05$ ). Mean ± S.E.

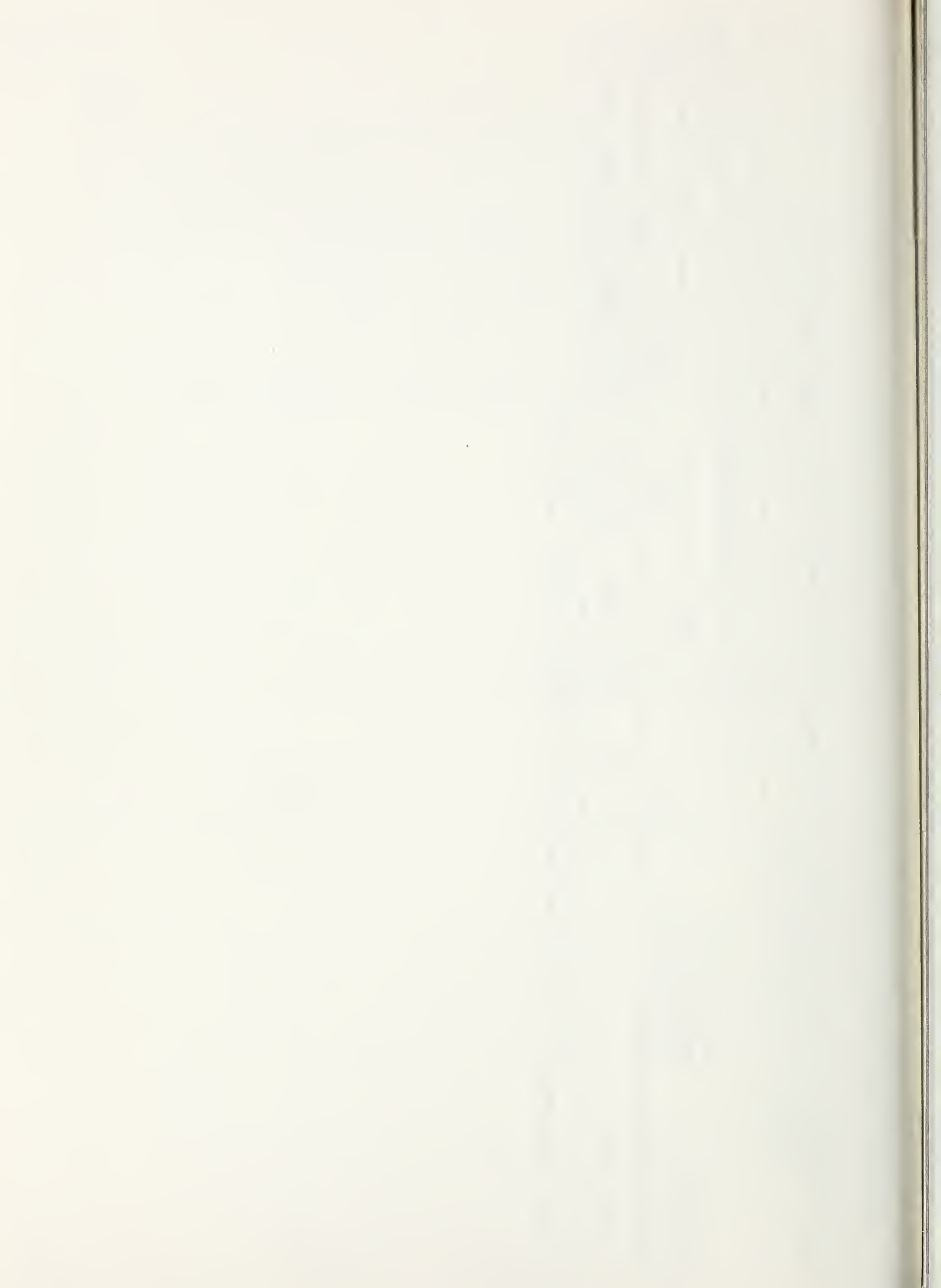


Table 89. Interaction effect of storage time (immediately following freezing, twelve months), initial storage temperature, final storage temperature and rate of freezing on Instron peak load values for roast beef cores

Evaluation time	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F		
			24	48	72
Immediately after freezing, 1 day			3.01 ± .18bc	3.43 ± .18bc	3.31 ± .18bc
					3.64 ± .18bc
12 months	-10	20T	2.84 ± .48bc	3.42 ± .48bc	4.03 ± .48abc
		20N	5.85 ± .48a	3.83 ± .48bc	2.64 ± .48c
	0	20T	4.06 ± .48abc	3.36 ± .48bc	4.60 ± .48ab
		20N	5.66 ± .48a	3.73 ± .48bc	4.13 ± .48abc
					4.09 ± .48abc

abc Any mean comparisons with the same letters are not different ( $P > .05$ ). Mean ± S.E.  
T = temperature abused. N = not temperature abused.



storage temperature. These nonabused roast peak load values were generally higher than their nonabused counterparts from roasts frozen at slower rates. Peak load values underwent a reduction from nine to twelve months for roasts frozen to 0°F in 72 hr (Table 90). Such was not the case for the other freezing rates.

General means and standard deviations for Newton values for cores throughout the study are presented in Table 91. Newton's are peak loads expressed as  $N/cm^2$  and thus account for any differences in core size that may have existed. Again, the major differences are the increase, for some reason, in values obtained for 0°F in 72 hr roasts following nine months storage. After six months of storage, Newton values increased in the roasts frozen to 0°F in 72 hr that were held at 0°F initially, compared to roasts frozen at that or any other rate and stored at -10°F initially (Table 92). Also at six months, Newton values increased for all treatment combinations initially stored at 0°F compared to those immediately following freezing (Table 93). Roasts initially stored at -10°F did not differ in Newton values compared to those noted right after freezing. These exact results were also found when shear force was expressed as kg.

As with shear force values, Newton values were substantially higher for roasts frozen to 0°F in 72 hr compared to other freezing rates when evaluations occurred after nine months storage (Table 94). Newton values were higher at nine and twelve months of storage compared to those obtained just after freezing (Table 95). An interaction of storage time, initial storage temperature, final storage temperature and freezing rate is given in Table 96. As with shear force values (kg) for this interaction (Table 84), much of the interaction seems to concentrate on the high Newton values found for roasts frozen to 0°F in 72 hr and initially stored at -10°F. The



Table 90. Interaction effect of storage time (nine, twelve months) and rate of freezing on Instron peak load values for roast beef cores

Evaluation time, months	Freezing rate, hours to 0°F			
	24	48	72	96
9	3.74 ± .14bc	3.46 ± .14bc	5.01 ± .14a	3.46 ± .14bc
12	3.42 ± .14bc	3.22 ± .14c	3.55 ± .14bc	3.94 ± .14b

abc Any mean comparisons with different letters are different (P<.05).  
Mean ± S.E.

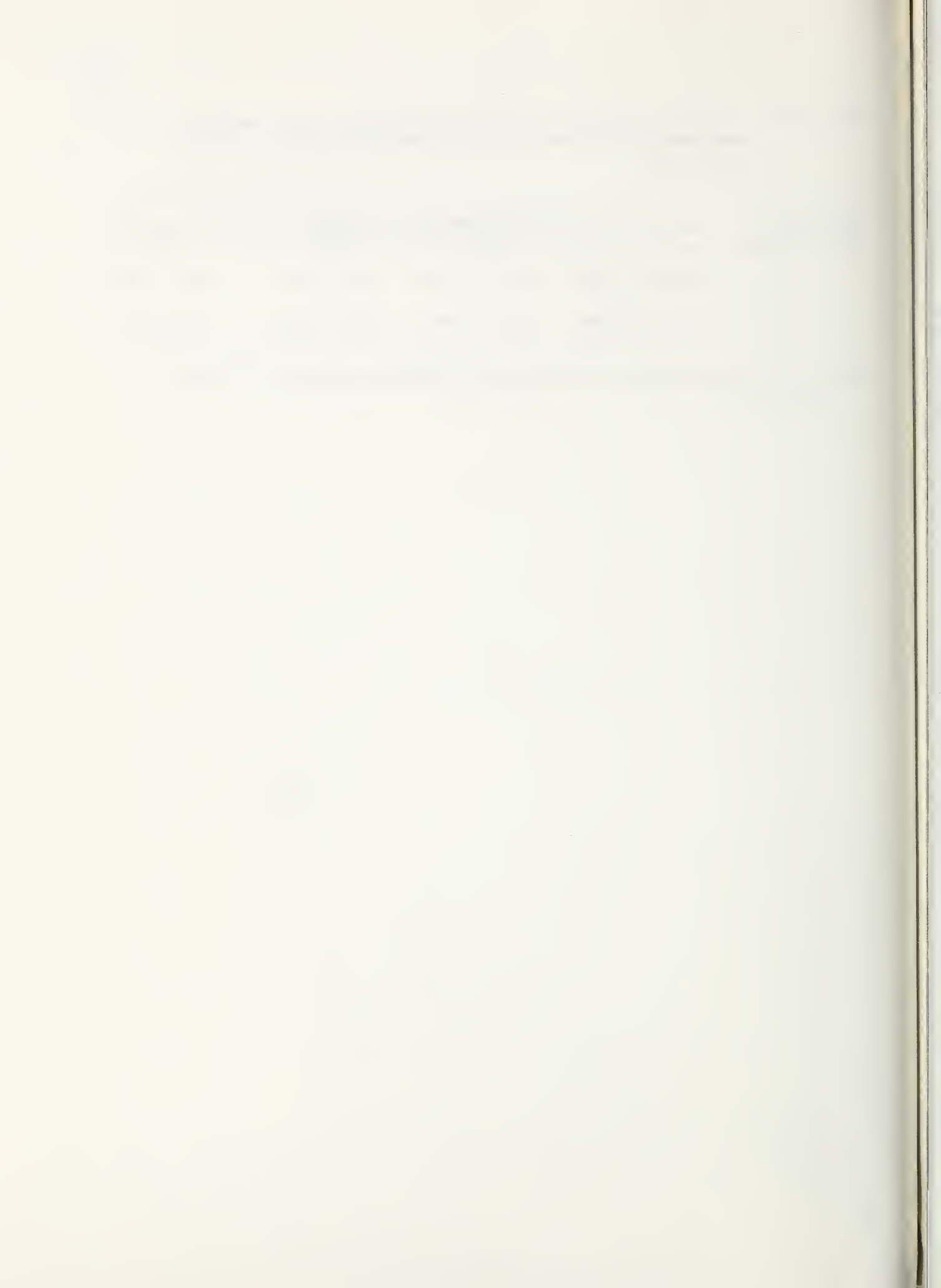




Table 91. General table illustrating Instron Newton values for roast beef cores throughout storage times and according to final storage temperature and rate of freezing - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		26.8 + 7.24	25.68 + 5.82	32.31 + 6.5	30.29 + 9.05
Immediately after freezing, 1 day		28.0 + 6.62	30.25 + 6.34	27.95 + 7.72	29.10 + 5.87
6 months	-10T	27.04 + 3.91	26.47 + 4.19	33.22 + 9.61	28.53 + 5.15
	0T	31.89 + 5.29	26.79 + 5.57	35.1 + 11.46	32.33 + 9.49
	20T	29.15 + 5.98	27.09 + 5.46	35.83 + 10.74	32.5 + 5.91
9 months	-10T	27.86 + 6.52	30.67 + 10.53	46.28 + 8.0	26.35 + 5.31
	0T	34.13 + 6.59	32.35 + 6.3	40.1 + 8.08	30.28 + 7.97
	20T	31.37 + 7.55	25.72 + 3.66	41.98 + 7.49	29.76 + 4.27
12 months	-10T	28.66 + 3.38	28.57 + 4.88	26.01 + 4.67	32.92 + 7.25
	0T	28.65 + 4.98	26.71 + 5.17	26.17 + 6.54	29.53 + 5.65
	20T	28.24 + 7.09	28.3 + 4.8	33.13 + 5.18	34.8 + 7.78
	20N	47.7 + 8.16	31.63 + 6.4	31.28 + 7.46	28.43 + 7.24

<sup>a</sup>Mean + S.D.; T = Temperature abused; N = Not temperature abused.



Table 92 . Interaction effect of initial storage temperature and rate of freezing on Instron Newton values for roast beef cores following six months storage

Initial storage temperature, °F	Freezing rate, hours to 0°F			
	24	48	72	96
-10	28.48 $\pm$ 1.62b	26.53 $\pm$ 1.62b	26.61 $\pm$ 1.62b	33.34 $\pm$ 1.62b
0	30.24 $\pm$ 1.62b	27.71 $\pm$ 1.62b	42.82 $\pm$ 1.62a	28.9 $\pm$ 1.62b

ab Any mean comparison with the same letters is not different ( $P>.05$ ); Mean  $\pm$  S.E.



Table 93. Effect of storage time (immediately following freezing, six months) on Instron Newton values for roast beef cores

		6 months storage			
		Initial Storage temperature, °F =		0	
Immediately following freezing, 1 day	28.44 ± .97ab	-10		-10	20
		Final Storage temperature, °F =			
		-10	20	-10	20
		25.52 ± 1.67b	29.3 ± 1.67ab	28.57 ± 1.67ab	32.61 ± 1.67a
				33.75 ± 1.67a	33.72 ± 1.67a

ab Means on the same line with the same letters are not different ( $P > .05$ ); Mean ± S.E.



Table 94. Effect of freezing rate on Instron Newton values for roast beef cores following nine months storage

Freezing rate, hours to 0°F			
24	48	72	96
31.12 $\pm$ 1.63b	29.58 $\pm$ 1.63b	42.79 $\pm$ 1.63a	28.8 $\pm$ 1.63b

ab Means on the same line with the same letters are not different ( $P > .05$ ); Mean  $\pm$  S.E.





Table 95. Effect of various storage time comparisons on Instron Newton values for roast beef cores

Evaluation times	
Immediately following freezing, 1 day	9 months
28.44 $\pm$ 1.53b	33.07 $\pm$ 1.53a
Immediately following freezing, 1 day <sup>C</sup>	12 months <sup>C</sup>
28.82 $\pm$ 1.30b	32.93 $\pm$ 1.30a

ab Differences between means on the same line with different letters are different ( $P < .05$ ); Mean  $\pm$  S.E.

<sup>C</sup>Includes only +20°F final storage at twelve months.



Table 96. Interaction effect of storage time (immediately following freezing, nine months), initial storage temperature, final storage temperature and rate of freezing on Instron Newton values for roast beef cores

Evaluation time	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to °F			
			24	48	72	96
Immediately after freezing, 1 day						
			27.97 ± 1.89cdefg	29.13 ± 1.89bcdefg	25.79 ± 1.89defg	30.88 ± 1.89bcdefg
9 months	-10	-10	23.76 ± 3.27fg	24.48 ± 3.27fg	52.51 ± 3.27a	19.48 ± 3.27g
		0	36.22 ± 3.27bcdef	31.71 ± 3.27bcdefg	42.66 ± 3.27abc	24.56 ± 3.27efg
		20	26.80 ± 3.27defg	24.68 ± 3.27efg	44.22 ± 3.27ab	26.82 ± 3.27defg
	0	-10	31.96 ± 3.27bcdefg	36.86 ± 3.27bcdef	40.06 ± 3.27abcd	33.21 ± 3.27bcdefg
		0	32.04 ± 3.27bcdefg	32.99 ± 3.27bcdefg	37.56 ± 3.27abcdef	36.01 ± 3.27bcdef
		20	35.95 ± 3.27bcdef	26.76 ± 3.27defg	39.74 ± 3.27abcde	32.7 ± 3.27bcdefg

abcdefg Any mean comparisons with different letters are different ( $P < .05$ ); Mean ± S.E.



interaction of initial storage temperature, storage time and freezing rate given in Table 97 is also due largely to the high Newton values found for 0°F in 72 hr freezing rate at nine months and just the 0°F initially stored product at six months for this freezing rate.

Temperature abuse in twelve-month-stored product produced higher Newton values for 0°F in 24 hr rates only compared to the other rates (Table 98). At twelve months, roasts initially stored at 0°F and finally at +20°F produced higher Newton values than roasts stored initially and finally at 0°F (Table 99). Various combinations of initial and final storage temperatures did not produce differences in Newton values compared to those detected immediately following freezing (Table 100). Generally, most combinations of initial storage temperature, freezing rate and temperature abuse after twelve months of storage did not alter Newton values compared to those originally found right after freezing (Table 101). In comparing nine vs twelve months storage times in conjunction with freezing rates, the only increase in Newton values at twelve months over nine months occurred for 0°F in 72 hr product (Table 102). This was similar to the differences noted for peak load (Table 90). Twelve months vs nine months storage produced a decrease in Newton values for roasts stored at 0°F, but not the other two temperatures (Table 103).

General values for roast beef core Instron modulus values are given in Table 104. As with other Instron values, roasts frozen to 0°F in 72 hr and stored either six or nine months were the most different from the other treatment combinations. Higher modulus values reflect greater stress or load in relation to peak elongation or strain. It would appear (Table 105) that freezing produced an increase in modulus values for roasts frozen to 0°F in 48 hr and 96 hr and a decrease in values for roasts frozen to 0°F in 72 hr.

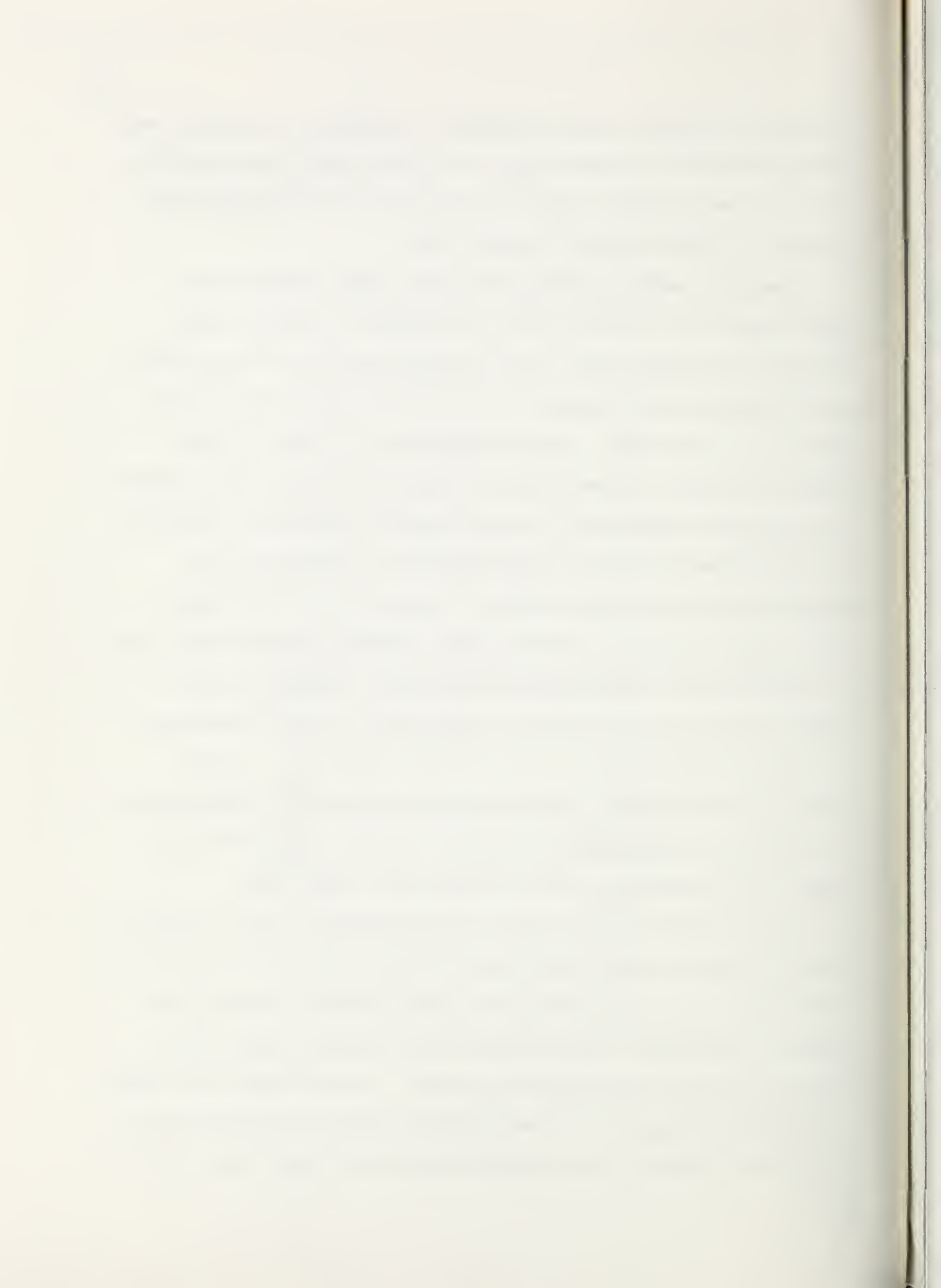


Table 97. Interaction effect of initial storage temperature, storage time (six, nine months) and freezing rate on Instron Newton values for roast beef cores

Initial storage temperature, °F	Evaluation time	Freezing rate, hours to 0°F			
		24	48	72	96
-10	6	28.5 ± 1.4c	26.5 ± 1.4c	26.6 ± 1.4c	33.3 ± 1.4bc
	9	30.7 ± 1.4c	26.6 ± 1.4c	44.9 ± 1.4a	27.4 ± 1.4c
0	6	30.2 ± 1.4c	27.7 ± 1.4c	42.8 ± 1.4a	28.9 ± 1.4c
	9	31.5 ± 1.4c	32.5 ± 1.4c	40.6 ± 1.4ab	30.2 ± 1.4c

abc Any mean comparison with the same letters is not different ( $P > .05$ ); Mean ± S.E.





Table 98. Interaction effect of temperature abuse and rate of freezing on Instron Newton values for roast beef cores following twelve months storage

Temperature abuse	Freezing rate, hours to 0°F			
	24	48	72	96
T	28.24 $\pm$ 2.62b	28.3 $\pm$ 2.62b	33.13 $\pm$ 2.62b	34.8 $\pm$ 2.62ab
N	47.7 $\pm$ 2.62a	31.63 $\pm$ 2.62b	31.28 $\pm$ 2.62b	28.43 $\pm$ 2.62b

ab Any mean comparison with the same letters is not different ( $P > .05$ ); Mean  $\pm$  S.E.

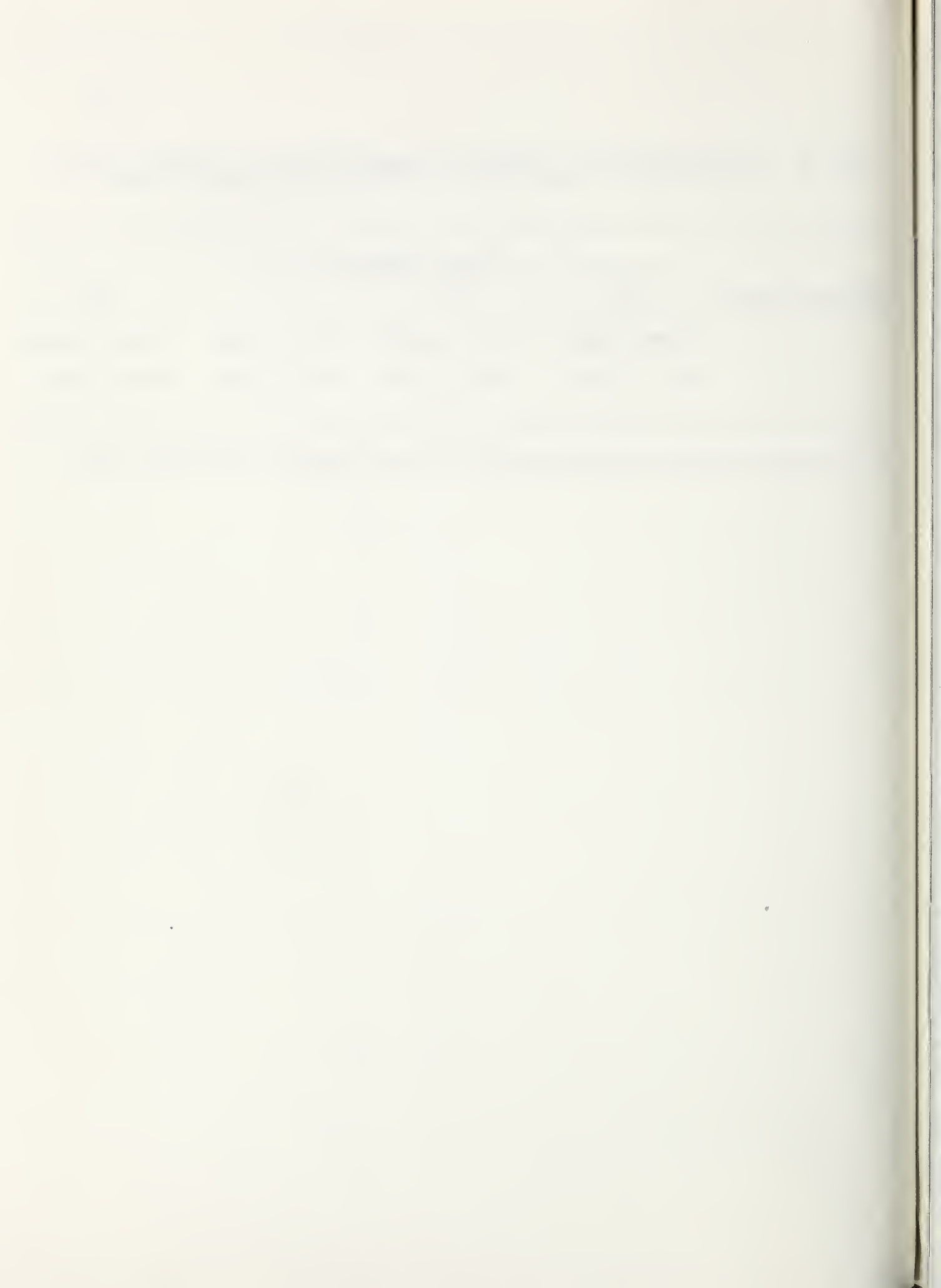


Table 99. Interaction effect of final storage temperature and initial storage temperature on Instron Newton values for roast beef cores following twelve months storage

Final storage temperature, °F	Initial storage temperature, 0°F	
	-10	0
-10	27.89 $\pm$ 1.11ab	30.18 $\pm$ 1.11ab
0	29.87 $\pm$ 1.11ab	25.66 $\pm$ 1.11b
20	29.8 $\pm$ 1.11ab	32.43 $\pm$ 1.11a

ab Any mean comparisons with the same letters are not different ( $P>.05$ ); Mean  $\pm$  S.E.



Table 100. Effect of storage time (immediately following freezing, twelve months) on Instron Newton values for roast beef cores

Immediately following freezing, 1 day	12 months storage			
	Initial Storage temperature, °F =	-10	0	20
Final Storage temperature, °F =	-10	0	-10	20
28.44 ± .88ab	26.95 ± 1.53b	28.92 ± 1.53ab	28.86 ± 1.53ab	31.13 ± 1.53ab
			26.61 ± 1.53a	33.38 ± 1.53b

ab Means on the same line with the same letters are not different ( $P > .05$ ); Mean ± S.E.

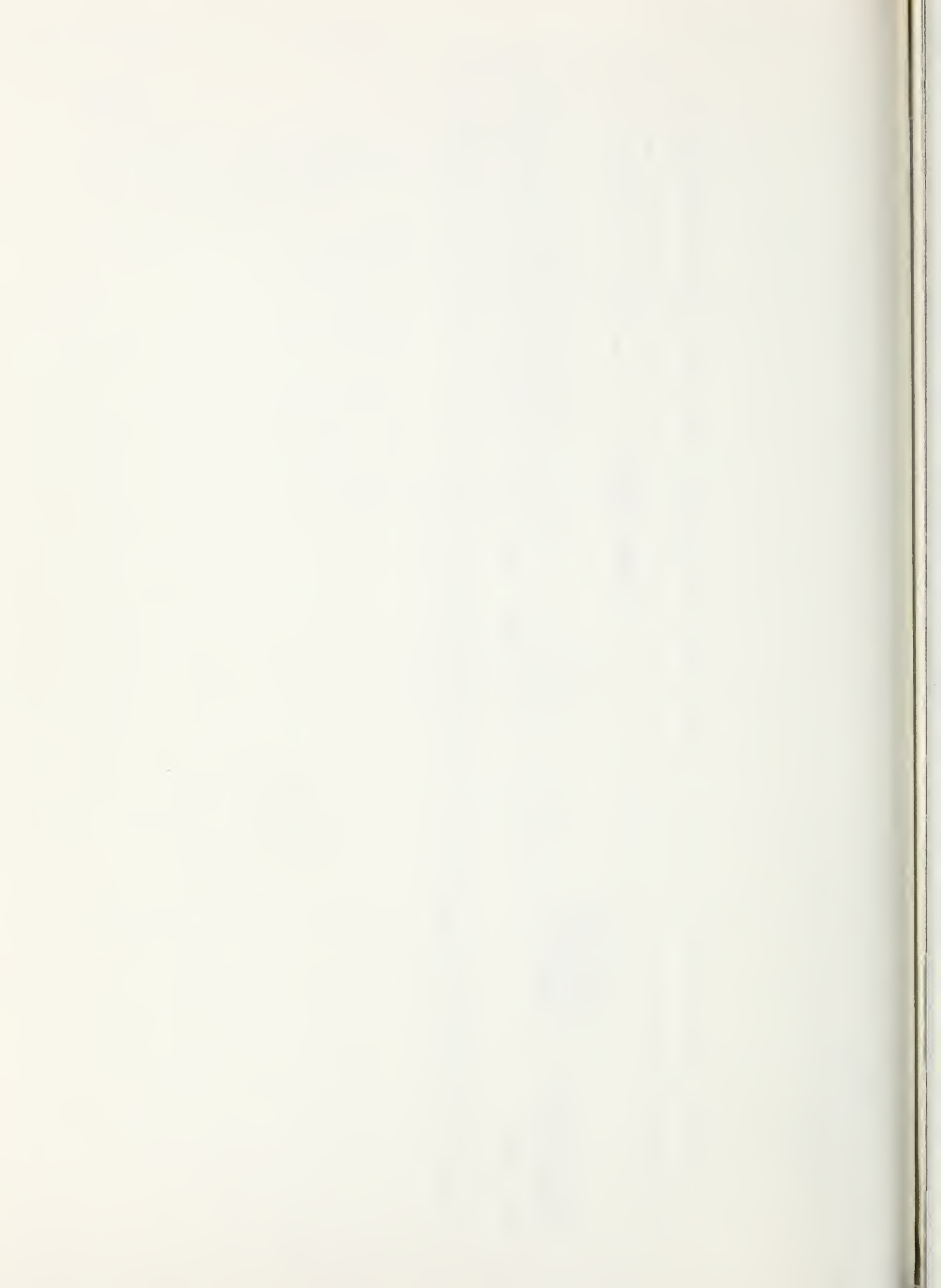


Table 101. Interaction effect of storage time (immediately following freezing, twelve months), initial storage temperature, temperature abuse and rate of freezing on Instron Newton values for roast beef cores

Evaluation time	Initial storage temperature, °F	Temperature abuse	Freezing rate, hours to 0°F			
			24	48	72	96
Immediately after freezing, 1 day			28.0 + 1.7c	30.25 + 1.7abc	27.95 + 1.7c	29.1 + 1.7bc
12 months	-10	T	23.27 + 4.51c	29.64 + 4.51bc	33.54 + 4.51abc	30.53 + 4.51abc
		N	48.47 + 4.51a	31.3 + 4.51abc	22.25 + 4.51c	26.48 + 4.51c
	0	T	33.29 + 4.51abc	29.2 + 4.51bc	37.03 + 4.51abc	35.53 + 4.51abc
		N	46.86 + 4.51ab	29.72 + 4.51bc	35.99 + 4.51abc	33.93 + 4.51abc

abc Any mean comparison with the same letters is not different ( $P > .05$ ); Mean + S.E.; T = Temperature abused;  
N = Not temperature abused.

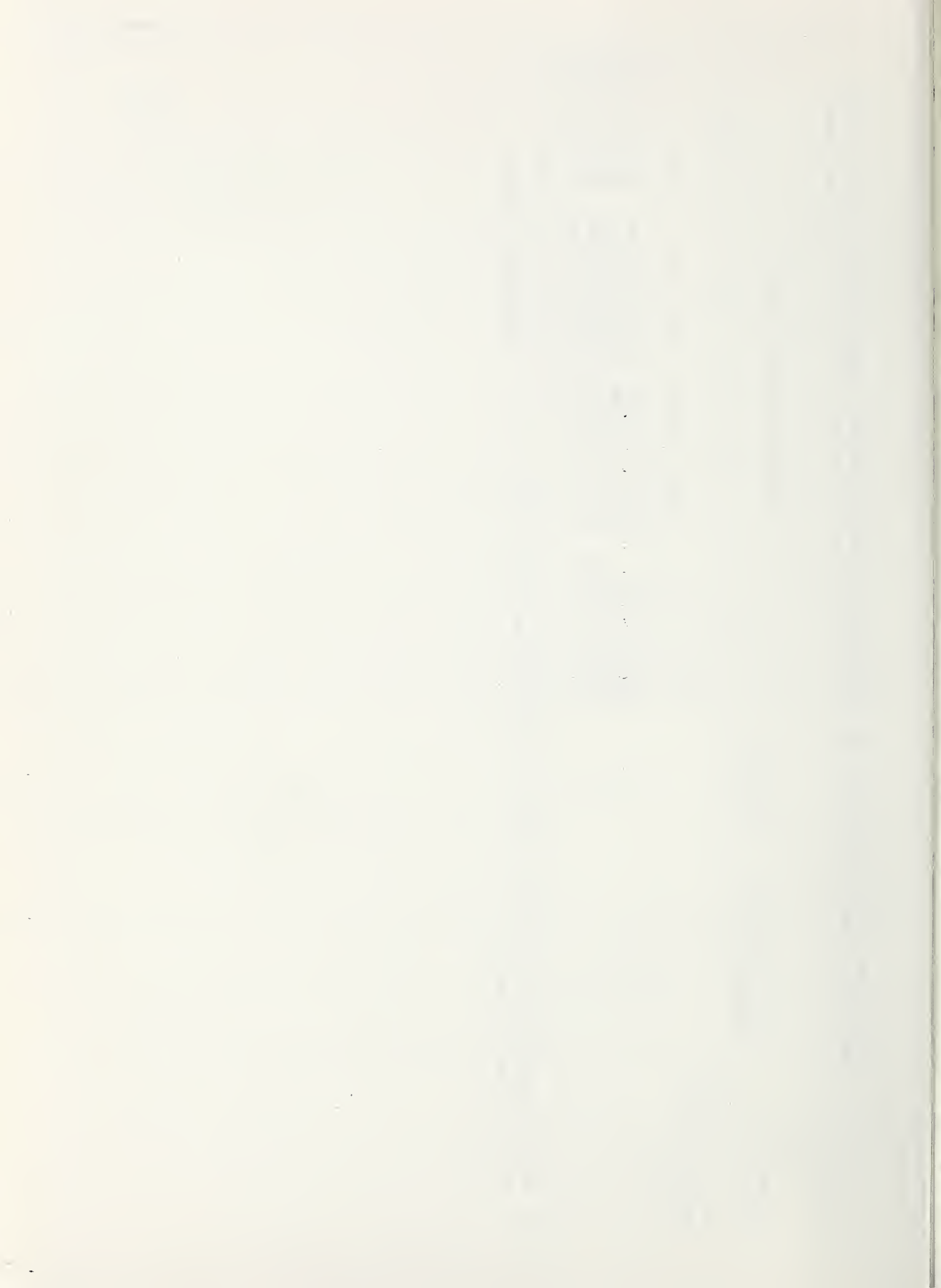




Table 102. Interaction effect of storage time (nine, twelve months) and rate of freezing on Instron Newton values for roast beef cores

Evaluation time, months	Freezing rate, hours to 0°F			
	24	48	72	96
9	31.12 $\pm$ 1.07b	29.58 $\pm$ 1.07b	42.79 $\pm$ 1.07a	28.8 $\pm$ 1.07b
12	28.52 $\pm$ 1.07b	27.86 $\pm$ 1.07b	28.44 $\pm$ 1.07b	32.42 $\pm$ 1.07b

ab Any mean comparison with the same letters is not different ( $P > .05$ ); Mean  $\pm$  S.E.;



Table 103. Interaction effect of storage time (nine, twelve months) and final storage temperature on Instron Newton values for roast beef cores

Evaluation time, months	Final storage temperature, °F		
	-10	0	20
9	32.79 $\pm$ .92ab	34.22 $\pm$ .92a	32.21 $\pm$ .92ab
12	29.04 $\pm$ .92bc	27.77 $\pm$ .92c	31.12 $\pm$ .92abc

ab Any mean comparison with different letters is different ( $P < .05$ );  
Mean  $\pm$  S.E.



Table 104. General table illustrating Instron modulus values for roast beef cores throughout storage time and according to final storage temperature and rate of freezing - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F		
		24	48	96
Before freezing		120.46 ± 35.87	120.32 ± 27.80	131.30 ± 16.34
Immediately after freezing, 1 day		120.87 ± 30.37	129.74 ± 18.58	114.77 ± 25.97
6 months	-10T	122.19 ± 23.35	117.63 ± 24.79	96.23 ± 29.49
	0T	137.69 ± 16.63	117.26 ± 23.89	96.3 ± 28.49
	20T	130.64 ± 19.93	119.38 ± 15.18	94.53 ± 33.08
9 months	-10T	129.92 ± 29.21	87.98 ± 28.26	73.16 ± 9.85
	0T	140.36 ± 18.38	96.09 ± 36.41	69.49 ± 7.99
	20T	128.44 ± 31.33	114.63 ± 23.0	70.77 ± 8.95
12 months	-10T	127.78 ± 16.16	123.9 ± 17.85	114.25 ± 19.14
	0T	128.45 ± 23.59	112.30 ± 25.63	114.69 ± 17.48
	20T	129.34 ± 25.73	126.25 ± 22.0	139.59 ± 16.76
	20N	73.75 ± 9.38	130.36 ± 23.13	127.63 ± 35.4
				121.95 ± 20.81
				120.50 ± 24.41
				123.96 ± 25.20
				136.55 ± 25.10
				139.23 ± 20.5
				116.36 ± 22.56
				132.17 ± 28.05
				125.96 ± 17.73
				136.78 ± 21.84
				122.6 ± 22.72
				145.44 ± 19.70
				125.67 ± 24.61

<sup>a</sup> a Mean ± S.D. T = temperature abused. N = not temperature abused.



Table 105. Interaction effect of storage time (immediately before and after freezing) and freezing rate on Instron modulus values for roast beef cores<sup>a</sup>

Evaluation time	Freezing rate, hours to 0°F		
	24	48	72
Before freezing	120.55 + 5.45	120.41 + 5.45	131.33 + 5.45
Immediately following freezing, 1 day	120.95 + 5.45	129.84 + 5.45	114.85 + 5.45

<sup>a</sup>Due to Instron programming changes, exact mean differences cannot be determined.





Following six months storage, 0°F initial storage produced a sizable reduction in modulus values compared to -10°F for roasts frozen to 0°F in 72 hr (Table 106). This reduced modulus for 0°F initial stored temperature product related to the high peak load values; which means that cores from these roasts had immediate and high stress when subjected to shearing.

At nine months of storage, roasts frozen to 0°F in 24 and 96 hr had predominately higher Instron modulus values compared especially to 0°F in 72 hr frozen product at all initial and final storage temperatures and 0°F in 48 hr roasts initially stored at 0°F and finally stored at -10 and 0°F (Table 107). In a comparison of modulus values at six and nine months (Table 108), the interaction largely was due to the lower values obtained for: (1) 0°F in 48 hr frozen product, stored nine months, initially stored at 0°F and finally stored at -10 and 0°F, (2) 0°F in 72 hr frozen product stored six months, initially stored at 0°F and stored at all three final temperatures, and (3) all initial and final storage temperatures of 0°F in 72 hr frozen product storage nine months. The interaction of storage time (nine, twelve months) initial and final storage temperature and freezing rate concentrated on the lower modulus values for 0°F 72 hr product at nine months and the lower values at twelve months for all rates for 0°F initial and final storage temperatures (Table 109). At twelve months, the absence of temperature abuse produced a reduction in modulus values only for the 0°F in 24 hr rate and not the other three rates (Table 110). Also at this storage time, roasts initially and finally held at 0°F displayed lower modulus values than roasts held at the same initial temperature, but at -10 and +20°F final temperatures (Table 111). These differences were not apparent for product initially stored at -10°F.

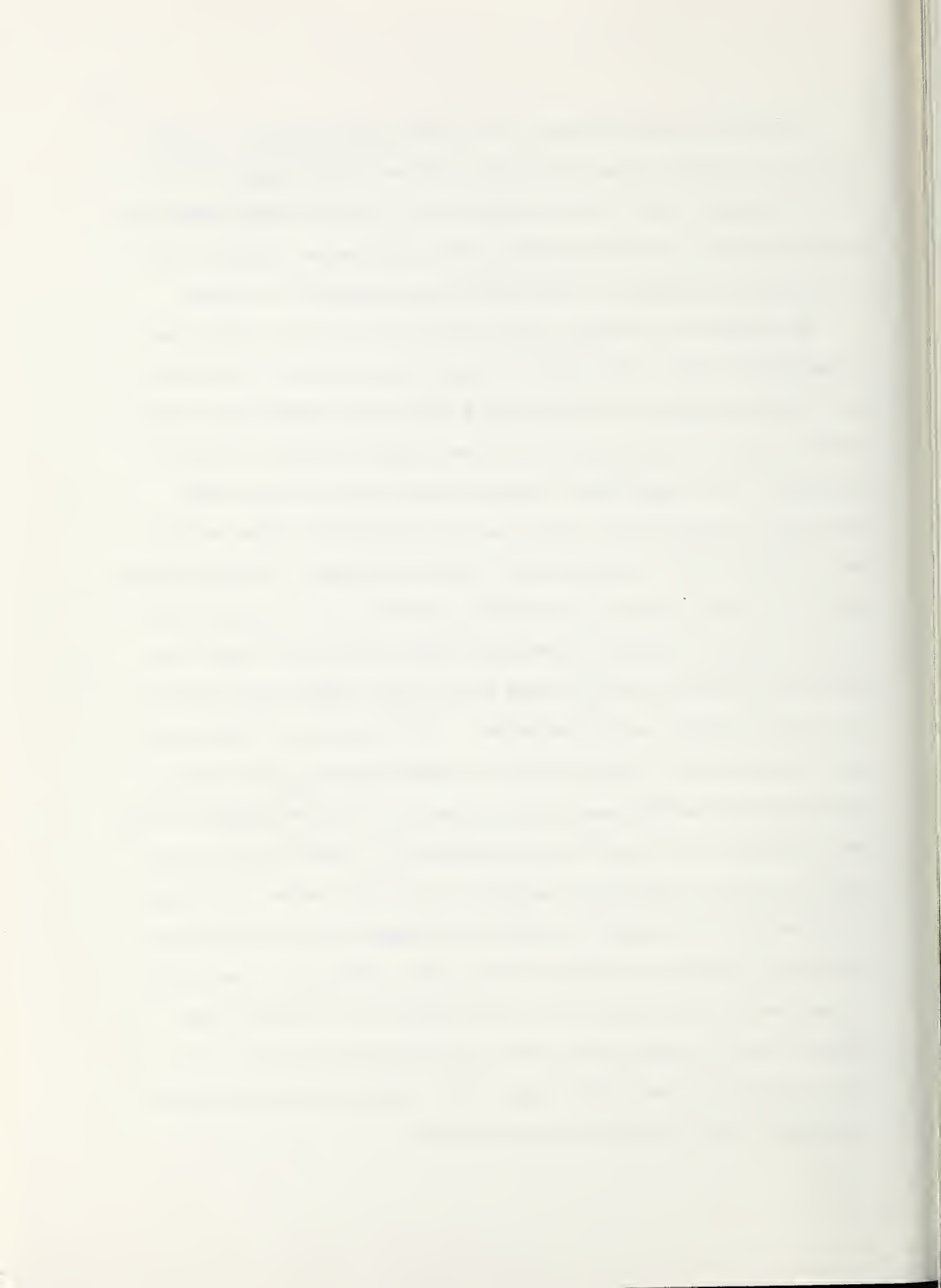


Table 106. Effect of initial storage temperature and rate of freezing on Instron modulus values for roast beef cores following six months storage

Initial storage temperature, °F	Freezing rate, hours to 0°F		
	24	48	72
-10	131.40 + 6.14a	118.14 + 6.14a	122.20 + 6.14a
0	128.95 + 6.14a	118.04 + 6.14a	69.17 + 6.14b
			124.71 + 6.14a

ab Any mean comparisons with the same letters are not different ( $P > .05$ ).  
Mean ± S.E.



Table 107. Interaction effect of initial storage temperature, final storage temperature, and rate of freezing on Instron modulus values for roast beef cores following nine months storage

Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24 .	48	72	96
-10	-10	118.9 + 7.2a	106.6 + 7.2abc	74.2 + 7.2bc	102.1 + 7.2abc
	0	142.8 + 7.2a	123.5 + 7.2a	70.1 + 7.2c	122.9 + 7.2a
	+20	116.2 + 7.2ab	107.1 + 7.2abc	68.9 + 7.2c	132.4 + 7.2a
0	-10	141.0 + 7.2a	69.3 + 7.2c	72.2 + 7.2c	130.6 + 7.2a
	0	137.9 + 7.2a	68.6 + 7.2c	68.9 + 7.2c	141.4 + 7.2a
	+20	140.7 + 7.2a	122.2 + 7.2a	72.6 + 7.2bc	119.5 + 7.2a

abc Any mean comparisons with different letters are different ( $P < .05$ ). Mean  $\pm$  S.E.



Table 108. Interaction effect of storage time (six, nine months), initial storage temperature, final storage temperature and rate of freezing on Instron modulus values for roast beef cores

Evaluation time, months		Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F			
				24	48	72	96
6	-10	-10	126.02 + 8.04abcde	113.26 + 8.04abcde	123.22 + 8.04abcde	125.13 + 8.04abcde	
		0	140.62 + 8.04a	117.18 + 8.04abcde	121.76 + 8.04abcde	151.11 + 8.04a	
		20	127.56 + 8.04abcde	123.99 + 8.04abcde	121.62 + 8.04abcde	149.11 + 8.04a	
		-10	118.36 + 8.04abcde	122.00 + 8.04abcde	69.23 + 8.04e	122.78 + 8.04abcde	
		0	134.77 + 8.04abc	117.34 + 8.04abcde	70.85 + 8.04de	121.99 + 8.04abcde	
9		20	133.73 + 8.04ab	114.76 + 8.04abcde	67.44 + 8.04e	129.35 + 8.04abcd	
	-10	-10	118.86 + 8.04abcde	106.63 + 8.04abcde	74.15 + 8.04bcde	102.11 + 8.04abcde	
		0	142.80 + 8.04a	123.56 + 8.04abcde	70.09 + 8.04de	122.91 + 8.04abcde	
		20	116.20 + 8.04abcde	107.12 + 8.04abcde	68.94 + 8.04e	132.41 + 8.04abc	
		-10	140.99 + 8.04a	69.32 + 8.04e	72.16 + 8.04e	130.61 + 8.04abcd	
		0	137.92 + 8.04a	68.63 + 8.04e	68.90 + 8.04e	141.44 + 8.04a	
		20	140.67 + 8.04a	122.15 + 8.04abcde	72.61 + 8.04cde	119.51 + 8.04abcde	

abcde Any mean comparisons with the same letters are not different ( $P>.05$ ). Mean  $\pm$  S.E.





Table 109. Interaction effect of storage time (nine, twelve months), initial storage temperature, final storage temperature and rate of freezing on Instron modulus values for roast beef cores

Evaluation time, months	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F		
			24	48	72
9	-10	-10	118.86 ± 7.78a	106.63 ± 7.78ab	74.15 ± 7.78b
		0	142.8 ± 7.78a	123.56 ± 7.78a	70.09 ± 7.78b
		20	116.2 ± 7.78ab	107.12 ± 7.78ab	68.93 ± 7.78b
	0	-10	140.99 ± 7.78a	69.32 ± 7.78b	72.16 ± 7.78b
		0	137.92 ± 7.78a	68.63 ± 7.78b	68.9 ± 7.78b
		20	140.67 ± 7.78a	122.15 ± 7.78a	72.61 ± 7.78b
12	-10	-10	130.82 ± 7.78a	115.55 ± 7.78ab	108.86 ± 7.78ab
		0	140.31 ± 7.78a	111.18 ± 7.78ab	124.34 ± 7.78a
		20	116.98 ± 7.78ab	128.38 ± 7.78a	133.1 ± 7.78a
	0	-10	124.75 ± 7.78a	132.31 ± 7.78a	119.65 ± 7.78a
		0	116.59 ± 7.78ab	113.41 ± 7.78ab	105.05 ± 7.78ab
		20	141.71 ± 7.78a	124.13 ± 7.78a	146.09 ± 7.78a
					102.11 ± 7.78ab
					122.91 ± 7.78a
					132.41 ± 7.78a
					130.61 ± 7.78a
					141.44 ± 7.78a
					119.51 ± 7.78a
					132.68 ± 7.78a
					131.20 ± 7.78a
					141.15 ± 7.78a
					140.87 ± 7.78a
					114.05 ± 7.78ab
					149.72 ± 7.78a

ab Any mean comparisons with the same letters are not different (P>.05). Mean ± S.E.



Table 110. Interaction effect of temperature abuse and rate of freezing on Instron modulus values for roast beef cores following twelve months storage

Temperature abuse	Freezing rate, hours to 0°F			
	24	48	72	96
T	129.34 $\pm$ 9.15a	126.25 $\pm$ 9.15a	139.59 $\pm$ 9.15a	145.44 $\pm$ 9.15a
N	73.75 $\pm$ 9.15b	130.36 $\pm$ 9.15a	164.25 $\pm$ 9.15a	125.66 $\pm$ 9.15a

ab Any mean comparisons with the same letter are not different ( $P > .05$ ).

Mean  $\pm$  S.E. Includes just +20°F product.



Table 111. Interaction effect of final storage temperature and initial storage temperature on Instron modulus values for roast beef cores following twelve months storage

Final storage temperature, °F	Initial storage temperature, °F	
	-10	0
-10	121.98 $\pm$ 3.59bc	129.39 $\pm$ 3.59ab
0	126.76 $\pm$ 3.59abc	112.28 $\pm$ 3.59c
20	129.90 $\pm$ 3.59ab	140.41 $\pm$ 3.59a

abc Any mean comparisons with different letters are different ( $P < .05$ ).  
 Mean  $\pm$  S.E.



General means and standard deviations for Instron fail energy values for roast beef cores are given in Table 112. Fail energy refers to the energy values (area under the curve) at 80% of peak load. Results and trends are somewhat variable, but it does appear that the fail energy values overall become larger with prolonged storage and as with other Instron measurements are largest for the 0°F in 72 hr freezing rate.

The effects of freezing rate at various storage times on fail energy values for roast beef cores are presented in Table 113. Both before and immediately following freezing, the slower (0°F in 72, 96 hr) freezing rates produced the larger fail energy values. However, at nine months, only the 0°F in 72 hr rate produced larger values and at twelve months only the 0°F in 96 hr rate generated larger values. Deleting the differences in fail energy values for cores before freezing resulted in values for the 0°F in 48 hr rate to now not to be different from the 0°F in 96 hr rate immediately following freezing (Table 114). After six months of storage, 0°F initial storage produced higher fail energy values than -10°F for roasts frozen to 0°F in 72 hr (Table 115). No such differences were detected for the other three rates. Removing the freezing rate differences before freezing, now resulted in the 0°F in 48 hr rate having higher fail energy values than the 0°F in 72 hr rate when roasts were initially stored at -10°F (Table 116).

Six, nine and twelve months storage all produced higher fail energy values than initially right after freezing (Table 117). After six months storage, fail energy values for roasts frozen to 0°F in 72 hr and initially stored at 0°F were higher than those obtained from any other rate, initial and final storage temperature combinations (Table 118). Adjusting the data for differences pre-freezing did not greatly alter differences between

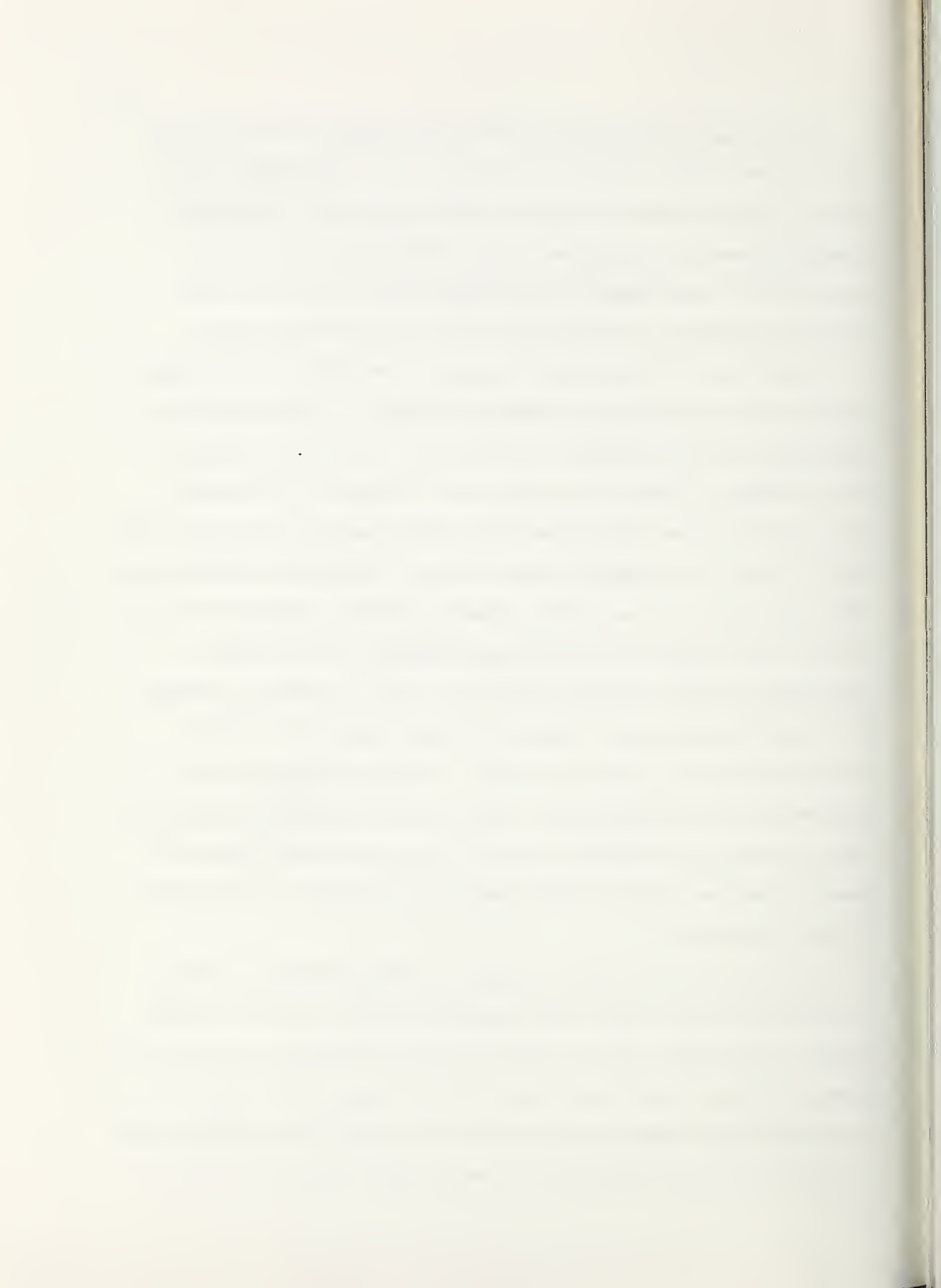




Table 112. General table illustrating Instron fall energy values for roast beef cores throughout storage and according to final storage temperature and rate of freezing - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F		
		24	48	72
Before freezing		2.83 ± .70	2.64 ± .75	3.51 ± .85
				3.94 ± 1.15
Immediately after freezing, 1 day		3.00 ± .68	3.19 ± .71	3.42 ± .81
				3.86 ± .76
6 months	-10T	3.80 ± .64	4.57 ± .87	4.34 ± 1.18
				3.90 ± 1.07
	0T	3.84 ± .71	3.89 ± .84	4.6 ± 1.85
				3.61 ± 1.05
	20T	3.90 ± .87	4.01 ± .77	4.63 ± 1.65
				4.12 ± .69
9 months	-10T	3.78 ± .67	4.02 ± 1.34	5.62 ± .85
				3.36 ± .86
	0T	4.14 ± .82	4.09 ± 1.01	5.20 ± 1.30
				3.72 ± 1.02
	20T	4.35 ± .94	3.39 ± .66	5.60 ± 1.41
				4.50 ± .88
12 months	-10T	3.64 ± .74	4.05 ± .85	3.61 ± .72
				4.44 ± 1.38
	0T	4.11 ± .86	3.72 ± .86	3.59 ± .96
				4.22 ± .89
	20T	3.74 ± .67	3.74 ± 1.11	4.26 ± .65
				5.12 ± .91
	20N	5.83 ± .84	4.31 ± .62	3.66 ± .74
				4.13 ± .99

<sup>a</sup> Mean ± S.D. T = temperature abused. N = not temperature abused



Table 113. Effect of freezing rate at various storage times on Instron fail energy values for roast beef cores.

Evaluation time	Freezing rate, hours 0°F			
	24	48	72	96
Before freezing	2.83 $\pm$ .25ab	2.64 $\pm$ .25b	3.51 $\pm$ .25ab	3.94 $\pm$ .25a
Immediately following freezing	3.00 $\pm$ .17b	3.19 $\pm$ .17b	3.42 $\pm$ .17ab	3.86 $\pm$ .17a
9 months	4.09 $\pm$ .25b	3.84 $\pm$ .25b	5.48 $\pm$ .25a	3.86 $\pm$ .25b
12 months	3.83 $\pm$ .20b	3.83 $\pm$ .20b	3.82 $\pm$ .20b	4.60 $\pm$ .20a

ab Means on the same line with different letters are different ( $P < .05$ ). Mean  $\pm$  S.E.



Table 114. Effect of freezing rate on Instron fail energy values for beef roast cores immediately following freezing - data adjusted for differences prior to freezing

Freezing rate, hours to 0°F			
24	48	72	96
3.05 ± .16b	3.25 ± .16ab	3.39 ± .16ab	3.79 ± .16a

ab Means on the same line with the same letters are not different ( $P > .05$ ).  
Mean ± S.E.

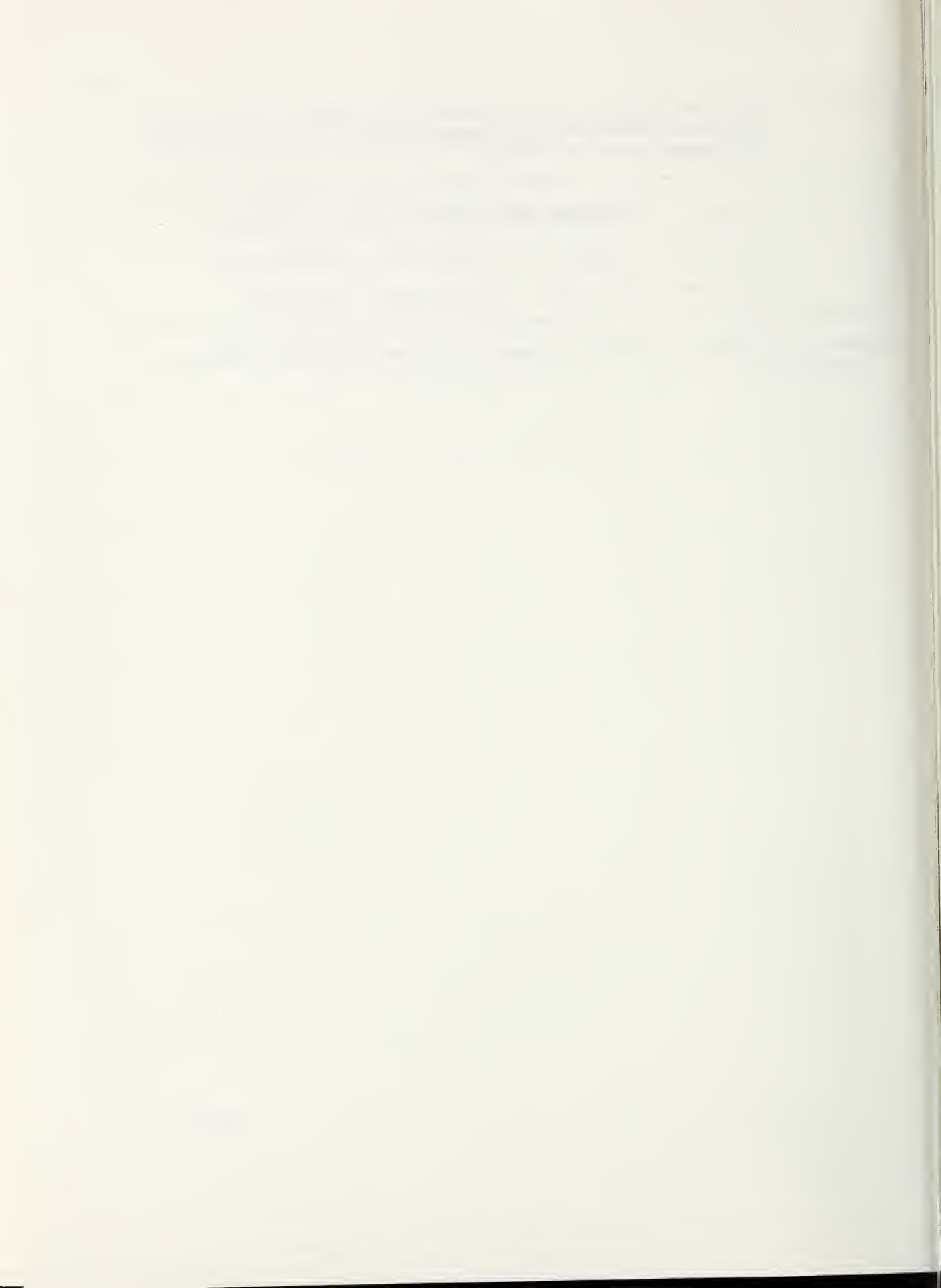


Table 115. Interaction effect of initial storage temperature and rate of freezing on Instron fail energy values for roast beef cores following six months storage

Initial storage temperature, °F	Freezing rate, hours to 0°F			
	24	48	72	96
-10	3.70 $\pm$ .21b	4.15 $\pm$ .21b	3.37 $\pm$ .21b	3.75 $\pm$ .21b
0	3.98 $\pm$ .21b	4.17 $\pm$ .21b	5.67 $\pm$ .21a	4.01 $\pm$ .21b

ab Any mean comparisons with the same letter are not different ( $P > .05$ ).  
Mean  $\pm$  S.E.





Table 116. Interaction effect of initial storage temperature and rate of freezing on Instron fail energy values for roast beef cores following six months storage - data adjusted for differences prior to freezing

Initial storage temperature, °F	Freezing rate, hours to 0°F			
	24	48	72	96
-10	3.82 $\pm$ .21bc	4.31 $\pm$ .21b	3.17 $\pm$ .21c	3.56 $\pm$ .21bc
0	4.03 $\pm$ .21bc	4.40 $\pm$ .21ab	5.60 $\pm$ .21a	3.74 $\pm$ .21bc

abc Any mean comparison with different letters are different ( $P < .05$ ).  
Mean  $\pm$  S.E.



Table 117. Effect of various storage time comparisons on Instron fail energy values for roast beef cores

<u>Evaluation time</u>	
<u>Immediately following freezing, 1 day</u>	<u>6 months</u>
3.32 $\pm$ .14b	4.10 $\pm$ .14a
<u>Immediately following freezing, 1 day</u>	<u>9 months</u>
3.32 $\pm$ .16b	4.32 $\pm$ .16a
<u>Immediately following freezing, 1 day</u>	<u>12 months</u>
3.32 $\pm$ .14b	4.02 $\pm$ .14a

ab Differences between means significant ( $P < .05$ ). Mean  $\pm$  S.E.



Table 118. Interaction effect of storage time (immediately after freezing, six months), initial storage temperature, final storage temperature, and rate of freezing on Instron fail energy values for roast beef cores

Evaluation time	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F		
			24	48	72
Immediately after freezing, 1 day			2.92 ± .25d	3.14 ± .25d	3.19 ± .25d
					4.04 ± .25bcd
6 months	-10	-10	3.56 ± .43cd	4.48 ± .43abcd	3.45 ± .43cd
					2.97 ± .43d
					3.85 ± .43cd
	0	0	3.40 ± .43cd	4.16 ± .43bcd	2.95 ± .43d
					3.95 ± .43cd
					3.85 ± .43cd
	+20	+20	3.86 ± .43cd	4.14 ± .43bcd	3.25 ± .43cd
					3.95 ± .43cd
					3.95 ± .43cd
	-10	-10	4.03 ± .43bcd	4.66 ± .43abcd	5.23 ± .43abc
					4.82 ± .43abcd
					4.82 ± .43abcd
	0	0	4.27 ± .43abcd	3.63 ± .43cd	6.25 ± .43a
					3.38 ± .43cd
					3.38 ± .43cd
	+20	+20	3.94 ± .43cd	3.88 ± .43cd	6.00 ± .43ab
					4.30 ± .43abcd
					4.30 ± .43abcd

abcd Any mean comparisons with the same letters are not different ( $P > .05$ ). Mean ± S.E.



treatments (Table 119). At nine months, the significant ( $P < .05$ ) interaction appears to be due largely to  $0^{\circ}\text{F}$  in 72 hr freezing rate product being different from various other freezing rate, initial and final storage temperature combinations (Table 120). Additional differences in fail energy values were detected in the comparison of just after freezing with nine months when values were adjusted for differences before freezing (Table 121). A significant ( $P < .05$ ) interaction of storage time (six, nine months) initial storage temperature, final storage temperature and freezing rate for fail energy values (Table 122) appear to be due mainly to rather minor and inconsequential differences.

Temperature abuse played a role with roasts stored twelve months where fail energy values were higher for  $0^{\circ}\text{F}$  in 24 hr product that received no temperature abuse compared to its temperature abused counterparts and non-temperature abused roasts from the other freezing rates (Table 123). With adjustment of values prior to freezing, fail energy values for roasts frozen to  $0^{\circ}\text{F}$  in 48 hr and not abused, did not differ from the other rates (Table 124).

Fail energy values for cores were higher following twelve months for roasts stored initially at  $0^{\circ}\text{F}$  and finally at  $+20^{\circ}\text{F}$  compared to values obtained just after freezing (Table 125). In a more extensive interaction involving storage time (immediately following freezing, twelve months) initial and final storage temperatures, freezing rate and temperature abuse (Table 126), the reason for the interaction from a logical aspect was the higher values noted for  $0^{\circ}\text{F}$ , finally stored at  $+20^{\circ}\text{F}$  and not receiving abuse vs many of the other treatment combinations. Adjustment of these values for differences prior to freezing, removed many of these differences (Table 127). Roasts stored for nine months and originally frozen to  $0^{\circ}\text{F}$  in





Table 119. Interaction effect of storage time (just after freezing, six months), initial and final storage temperature and rate of freezing on Instron fail energy values for roast beef cores - data adjusted for differences prior to freezing

Evaluation time	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F			
			24	48	72	96
Immediately following freezing, 1 day						
6 months	-10	-10	2.94 + .25d	3.19 + .25cd	3.15 + .25d	3.98 + .25bcd
		0	3.58 + .43cd	4.53 + .43abcd	3.42 + .43cd	2.92 + .43d
		20	3.42 + .43cd	4.21 + .43bcd	2.91 + .43d	3.79 + .43cd
			3.88 + .43cd	4.20 + .43bcd	3.22 + .43cd	3.89 + .43cd
	0	-10	4.05 + .43bcd	4.71 + .43abcd	5.19 + .43abc	4.76 + .43abcd
		0	4.29 + .43abcd	3.68 + .43cd	6.22 + .43a	3.32 + .43cd
		20	3.96 + .43bcd	3.93 + .43cd	5.96 + .43ab	4.24 + .43abcd

abcd Any mean comparison with the same letters are not different ( $P > .05$ ). Mean + S.E.

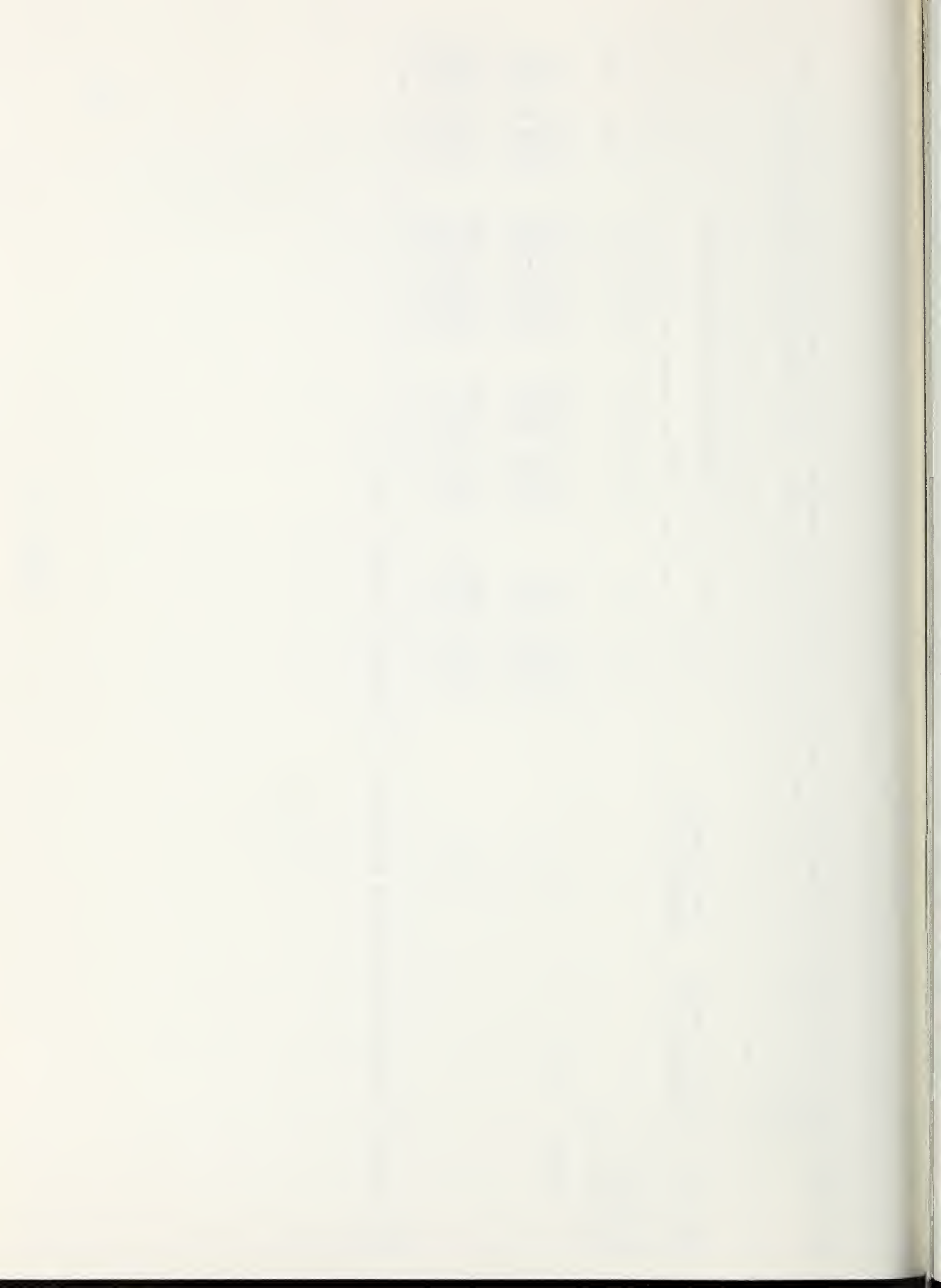


Table 120. Interaction effect of storage time (immediately after freezing, nine months), initial storage temperature, final storage temperature, and rate of freezing on Instron fall energy values for roast beef cores

Evaluation time	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F			
			24	48	72	96
Immediately after freezing, 1 day			2.92 + .27b	3.14 + .27b	3.19 + .27b	4.04 + .27ab
9 months	-10	-10	3.34 + .47b	3.37 + .47b	5.40 + .47a	3.14 + .47b
		0	4.60 + .47ab	4.53 + .47ab	4.82 + .47ab	2.98 + .47b
		20	3.76 + .47ab	3.66 + .47ab	5.78 + .47a	4.34 + .47ab
	0	-10	4.23 + .47ab	4.68 + .47ab	5.85 + .47a	3.58 + .47b
		0	3.68 + .47ab	3.66 + .47ab	5.59 + .47a	4.46 + .47ab
		20	4.94 + .47ab	3.12 + .47b	5.43 + .47a	4.67 + .47ab

ab Any mean comparisons with the same letters are not different ( $P > .05$ ). Mean + S.E.



Table 121. Interaction effect of storage time (immediately following freezing - nine months), initial and final storage temperature and rate of freezing on Instron fail energy values for roast beef cores - data adjusted for differences prior to freezing

Evaluation time	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F			
			24	48	72	96
Immediately following freezing, 1 day						
9 months	-10		2.98 + .27e	3.28 + .27de	3.09 + .27e	3.88 + .27abcde
		-10	3.39 + .47cde	3.51 + .47bcde	5.30 + .47abcd	2.99 + .47e
		0	4.65 + .47abcde	4.66 + .47abcde	4.72 + .47abcde	2.82 + .47e
	0	20	3.82 + .47abcde	3.79 + .47abcde	5.69 + .47ab	4.18 + .47abcde
		-10	4.28 + .47abcde	4.81 + .47abcde	5.76 + .47a	3.42 + .47cde
		0	3.74 + .47abcde	3.79 + .47abcde	5.50 + .47abc	4.31 + .47abcde
		20	5.00 + .47abcde	3.26 + .47de	5.33 + .47abcd	4.51 + .47abcde

abcde Any mean comparison with different letters is different (P<.05). Mean + S.E.



Table 122. Interaction effect of storage time (six, nine months), initial storage temperature, final storage temperature and rate of freezing on Instron fall energy values for roast beef cores

Evaluation time, months	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F			
			24	48	72	96
6	-10	-10	3.66 ± .45ab	4.37 ± .45ab	3.60 ± .45ab	3.13 ± .45b
		0	3.50 ± .45ab	4.04 ± .45ab	3.10 ± .45b	4.00 ± .45ab
	0	20	3.96 ± .45ab	4.03 ± .45ab	3.41 ± .45ab	4.11 ± .45ab
		-10	3.93 ± .45ab	4.78 ± .45ab	5.08 ± .45ab	4.67 ± .45ab
9	-10	0	4.17 ± .45ab	3.74 ± .45ab	6.10 ± .45a	3.22 ± .45ab
		20	3.85 ± .45ab	4.00 ± .45ab	5.84 ± .45ab	4.14 ± .45ab
	0	-10	3.43 ± .45ab	3.26 ± .45ab	5.55 ± .45ab	3.30 ± .45ab
		20	4.70 ± .45ab	4.42 ± .45ab	4.97 ± .45ab	3.13 ± .45b
	-10	20	3.86 ± .45ab	3.55 ± .45ab	5.93 ± .45ab	4.49 ± .45ab
		-10	4.13 ± .45ab	4.79 ± .45ab	5.70 ± .45ab	3.42 ± .45ab
	0	0	3.59 ± .45ab	3.77 ± .45ab	5.44 ± .45ab	4.31 ± .45ab
		20	4.84 ± .45ab	3.24 ± .45ab	5.27 ± .45ab	4.51 ± .45ab

ab Any mean comparisons with the same letters are not different ( $P > .05$ ). Mean ± S.E.





Table 123. Interaction effect of temperature abuse and rate of freezing on Instron fail energy values for roast beef cores following twelve months of storage

Temperature abuse	Freezing rate, hours to 0°F			
	24	48	72	96
T	3.74 $\pm$ .34b	3.74 $\pm$ .34b	4.26 $\pm$ .34b	5.12 $\pm$ .34ab
N	5.83 $\pm$ .34a	4.31 $\pm$ .34b	3.66 $\pm$ .34b	4.13 $\pm$ .34b

ab Any mean comparisons with the same letters are not different ( $P > .05$ ). Mean  $\pm$  S.E. T = temperature abused. N = Not temperature abused.



Table 124. Interaction effect of temperature abuse and rate of freezing on Instron fail energy values for beef roast cores following twelve months storage - data adjusted for differences prior to freezing

Temperature abuse	Freezing rate, hours to 0°F			
	24	48	72	96
T	3.85 ± .32b	3.99 ± .32b	4.08 ± .32b	4.83 ± .32ab
N	5.98 ± .32a	4.44 ± .32ab	3.66 ± .32b	3.97 ± .32b

ab Any mean comparison with the same letters is not different ( $P > .05$ ).

Mean ± S.E. T = temperature abused, N = not temperature abused.

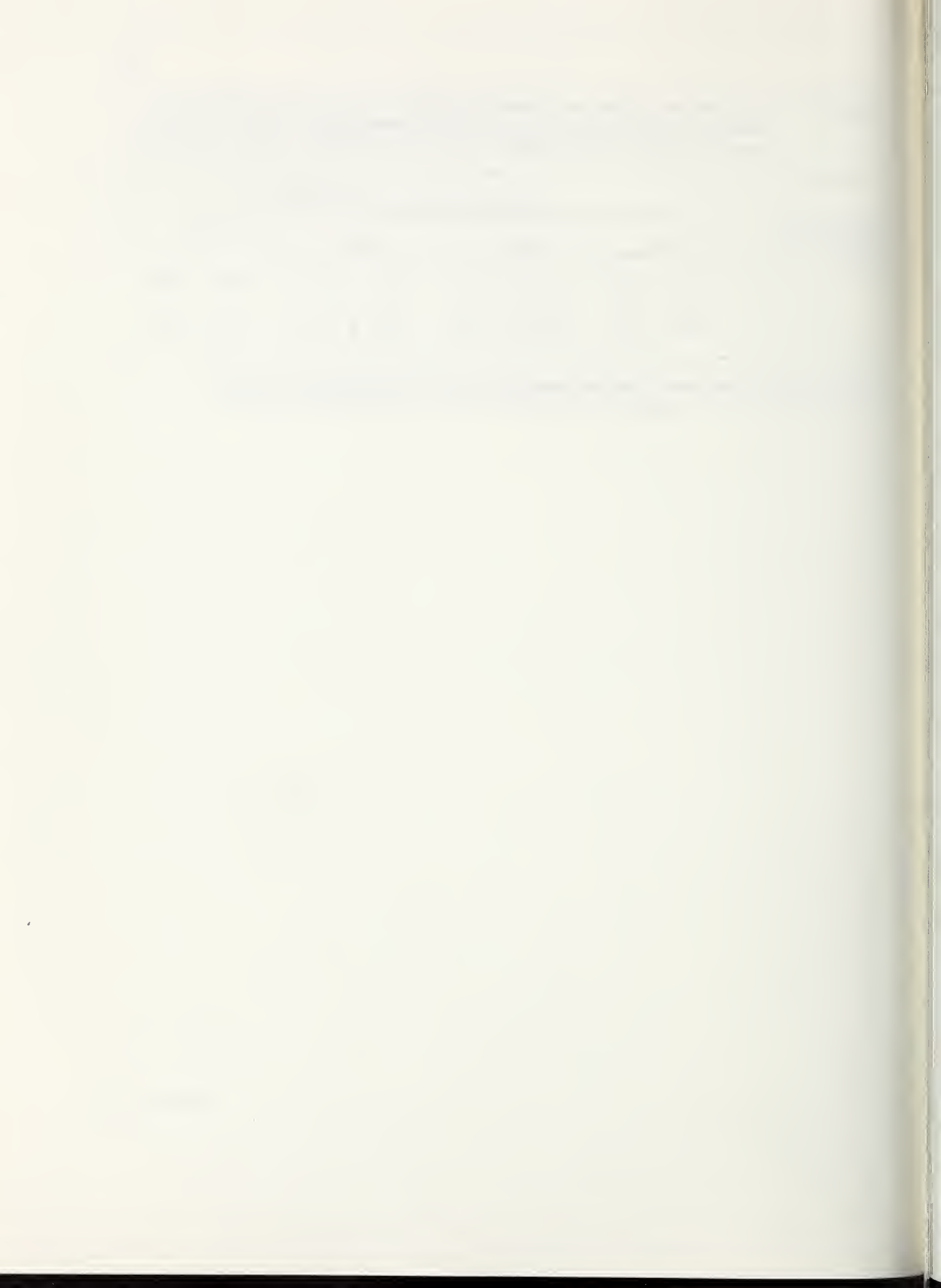


Table 125. Effect of storage time (immediately following freezing, twelve months) on Instron fail energy values for roast beef cores

		12 Months Storage			
Immediately following freezing, 1 day	Initial storage temperature, °F =				
	Final storage Temperature, °F =				
		-10	0	20	-10
3.32 ± .16b		3.59 ± .27ab	3.99 ± .27ab	4.06 ± .27ab	4.28 ± .27ab
					3.83 ± .27ab
					4.37 ± .27a

ab Means on the same line with different letters are different (P<.05). Mean ± S.E.



Table 126. Interaction effect of storage time (immediately after freezing, twelve months), initial storage temperature, final storage temperature and rate of freezing on Instron fall energy values for beef cores

Evaluation time	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F		
			24	48	72
Immediately after freezing, 1 day			3.00 ± .19e	3.19 ± .19de	3.42 ± .19cde
					3.86 ± .19bcde
12 months	-10	20T	3.77 ± .50bcde	3.81 ± .50bcde	4.11 ± .50bcde
					4.71 ± .50abcde
	20N		6.20 ± .50a	4.18 ± .50bcde	3.27 ± .50de
					3.64 ± .50bcde
	0	20T	3.87 ± .50bcde	3.75 ± .50bcde	4.87 ± .50abcde
					5.19 ± .50abc
	20N		5.31 ± .50ab	4.37 ± .50bcde	3.58 ± .50bcde
					4.97 ± .50abcde

abcde Any mean comparisons with the same letters are not different (P>.05). Mean ± S.E.  
T = temperature abused. N = not temperature abused.





Table 127. Interaction effect of storage time (immediately following freezing, twelve months), temperature abuse, initial storage temperature and rate of freezing on Instron fall energy values for roast beef cores - data adjusted for differences prior to freezing

Evaluation time	Temperature abuse	Final storage temperature, 0°F	Freezing rate, hours to 0°F			
			24	48	72	96
Immediately following freezing, 1 day						
			3.09 + .19c	3.31 + .19c	3.36 + .19bc	3.72 + .19bc
12 months	T	-10	3.86 + .50bc	3.93 + .50bc	4.05 + .50bc	4.56 + .50abc
		0	3.95 + .50bc	3.87 + .50bc	4.81 + .50abc	5.04 + .50abc
	N	-10	6.28 + .50a	4.30 + .50abc	3.21 + .50c	3.49 + .50bc
		0	5.39 + .50ab	4.49 + .50abc	3.52 + .50bc	4.83 + .50abc

abc Any mean comparison with the same letters is not different ( $P > .05$ ). Mean + S.E. T = temperature abused, N = not temperature abused.



72 hr had higher fail energy values than twelve-month-stored roasts at this freezing rate and other freezing rates at nine months (Table 128).

The next section deals with similar Instron values, but now obtained from roast beef slices rather than cores. Peak load values presented in a general form throughout most of the study are in Table 129 and show a great deal of variability. Immediately following freezing, roasts frozen to 0°F in 96 hr displayed higher peak load values than roasts frozen to 0°F in 72 hr (Table 130). This was not noted for roast beef cores. Following twelve months of storage, roast beef slices from roasts frozen to 0°F in 24 hr, initially stored at 0°F, and finally stored at +20°F produced high peak load values, whereas roasts frozen to 0°F in 72 hr, initially stored at -10°F and finally stored at -10°F generated very low peak load values for beef slices (Table 131). Temperature abuse produced an increase in peak load values at twelve months only for roasts frozen to 0°F in 24 hr and initially stored at 0°F (Table 132). An interaction involving time (six, nine months) initial storage temperature and freezing rates was detected for peak load values for slices by analysis of variance, but not by HSD (Table 133).

General mean information pertaining to Newton values for slices is presented in Table 134. Considerable variation (S.D.) can be noted with apparent trends not detectable. Immediately following freezing, slices from roasts frozen to 0°F in 96 hr produced higher Newton values than the other three rates (Table 135). A significant freezing rate with before-after freezing was found for slice Newton values, but no mean differences exceeded the HSD value (Table 136). Before freezing values were substantially higher than immediately post-freezing values (Table 137).



Table 128. Interaction effect of storage time (nine, twelve months) and rate of freezing on Instron fail energy values for roast beef cores

Evaluation time, months	Freezing rate, hours to 0°F			
	24	48	72	96
9	4.09 $\pm$ .20b	3.84 $\pm$ .20b	5.48 $\pm$ .20a	3.86 $\pm$ .20b
12	3.83 $\pm$ .20b	3.83 $\pm$ .20b	3.82 $\pm$ .20b	4.60 $\pm$ .20ab

ab Any mean comparisons with different letters are different ( $P < .05$ ).  
Mean  $\pm$  S.E.



Table 129. General table illustrating Instron peak load values for roast beef slices throughout storage and according to final storage temperature and freezing rate - no statistical analysis<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		4.44 $\pm$ 1.11	4.43 $\pm$ .97	4.34 $\pm$ .88	5.02 $\pm$ .93
Immediately after freezing, 1 day		4.47 $\pm$ 1.05	4.29 $\pm$ 1.11	4.02 $\pm$ .94	5.21 $\pm$ .88
6 months	-10T	3.41 $\pm$ .39	4.74 $\pm$ .57	4.40 $\pm$ .84	5.21 $\pm$ .63
	0T	5.03 $\pm$ .76	4.48 $\pm$ .72	4.35 $\pm$ .97	5.17 $\pm$ 1.46
	20T	4.36 $\pm$ 1.18	4.28 $\pm$ .74	4.44 $\pm$ 1.15	4.68 $\pm$ .76
9 months	-10T	4.29 $\pm$ .72	3.89 $\pm$ .87	4.79 $\pm$ 1.12	5.32 $\pm$ 1.49
	0T	4.67 $\pm$ 1.21	4.26 $\pm$ .58	4.35 $\pm$ .90	4.84 $\pm$ 1.50
	20T	5.23 $\pm$ 1.04	4.28 $\pm$ .68	4.80 $\pm$ 1.02	4.63 $\pm$ 1.08
12 months	-10T	4.73 $\pm$ 1.08	4.26 $\pm$ .93	3.53 $\pm$ .78	4.34 $\pm$ .79
	0T	4.53 $\pm$ .97	3.68 $\pm$ .55	3.86 $\pm$ 1.00	4.58 $\pm$ .92
	20T	5.82 $\pm$ 1.64	3.98 $\pm$ 1.32	4.20 $\pm$ .53	5.17 $\pm$ 1.06
	20N	3.86 $\pm$ .88	5.33 $\pm$ 1.34	4.91 $\pm$ .73	5.10 $\pm$ .90

<sup>a</sup>Mean  $\pm$  S.D., T = temperature abused; N = not temperature abused.





Table 130. Effect of freezing rate on Instron peak load values for roast beef slices immediately following freezing

Freezing rate, hours to 0°F			
24	48	72	96
4.47 $\pm$ .28ab	4.29 $\pm$ .28ab	4.02 $\pm$ .28b	5.21 $\pm$ .28a

ab Means on the same line with different letters are different ( $P < .05$ ).  
Mean  $\pm$  S.E.



Table 131. Interaction effect of initial storage temperature, final storage temperature and rate of freezing on Instron peak load values for roast beef slices following twelve months of storage

Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
-10	-10	4.48 ± .45abc	3.99 ± .45bc	2.90 ± .45c	3.99 ± .45bc
	0	3.94 ± .45bc	3.79 ± .45bc	4.49 ± .45abc	4.42 ± .45abc
	20	4.52 ± .45abc	3.06 ± .45c	4.44 ± .45abc	5.85 ± .45ab
0	-10	4.99 ± .45abc	4.53 ± .45abc	4.15 ± .45bc	4.69 ± .45abc
	0	5.13 ± .45abc	3.56 ± .45bc	3.23 ± .45bc	4.75 ± .45abc
	20	7.11 ± .45a	4.90 ± .45abc	3.96 ± .45bc	4.48 ± .45abc

abc Any mean comparison with the same letters is not different ( $P > .05$ ). Mean ± S.E.



Table 132. Interaction effect of temperature abuse, initial storage temperature and rate of freezing on Instron peak load values for roast beef slices following twelve months storage

Temperature abuse	Initial storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
T	-10	4.52 $\pm$ .63ab	3.06 $\pm$ .63b	4.44 $\pm$ .63ab	5.85 $\pm$ .63ab
	0	7.11 $\pm$ .63a	4.90 $\pm$ .63ab	3.96 $\pm$ .63ab	4.48 $\pm$ .63ab
N	-10	4.32 $\pm$ .63ab	5.76 $\pm$ .63ab	5.15 $\pm$ .63ab	4.67 $\pm$ .63ab
	0	3.41 $\pm$ .63b	4.90 $\pm$ .63ab	4.67 $\pm$ .63ab	5.54 $\pm$ .63ab

ab Any mean comparison with the same letters is not different ( $P > .05$ ).

Mean  $\pm$  S.E. T = temperature abused; N = not temperature abused.



Table 133. Interaction effect of storage time (six, nine months), initial storage temperature and rate of freezing on Instron peak load values for roast beef slices<sup>a</sup>

Evaluation time, months	Initial storage temperature, °F	Freezing rates, hours to 0°F			
		24	48	72	96
6	-10	4.58 $\pm$ .32	4.30 $\pm$ .32	4.06 $\pm$ .32	4.99 $\pm$ .32
	0	3.95 $\pm$ .32	4.70 $\pm$ .32	4.73 $\pm$ .32	5.04 $\pm$ .32
9	-10	4.59 $\pm$ .32	4.32 $\pm$ .32	4.91 $\pm$ .32	4.25 $\pm$ .32
	0	4.87 $\pm$ .32	3.97 $\pm$ .32	4.39 $\pm$ .32	5.61 $\pm$ .32

<sup>a</sup> Interaction significant by analysis of variance, but not by HSD. Mean  $\pm$  S.E.





Table 134. General table illustrating Instron Newton values for roast beef slices throughout storage and according to final storage temperature and rate of freezing - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		124.26 ± 53.6	112.81 ± 41.77	100.46 ± 34.0	116.76 ± 35.99
Immediately after freezing, 1 day		91.53 ± 38.53	93.34 ± 35.28	76.39 ± 20.16	128.99 ± 32.96
6 months	-10T	71.64 ± 9.22	98.00 ± 28.49	102.35 ± 26.57	82.69 ± 11.69
	0T	94.25 ± 24.87	93.17 ± 25.02	98.55 ± 31.03	77.15 ± 23.19
	20T	91.37 ± 25.74	86.27 ± 25.39	98.09 ± 26.96	77.97 ± 24.87
9 months	-10T	83.92 ± 11.5	87.93 ± 22.57	101.25 ± 42.00	112.77 ± 38.73
	0T	93.34 ± 37.43	103.08 ± 23.31	93.29 ± 18.40	90.61 ± 36.26
	20T	95.71 ± 23.91	88.38 ± 28.56	113.56 ± 47.49	96.57 ± 32.62
12 months	-10T	104.22 ± 32.37	94.34 ± 20.76	70.3 ± 18.3	111.27 ± 38.71
	0T	88.08 ± 27.31	83.34 ± 19.98	78.9 ± 21.3	110.98 ± 43.65
	20T	113.09 ± 33.42	82.65 ± 20.0	87.1 ± 22.3	114.33 ± 45.68
	20N	92.3 ± 23.75	96.65 ± 26.67	112.32 ± 33.16	92.44 ± 37.28

<sup>a</sup>Mean ± S.D.; T = Temperature abused; N = Not temperature abused.



Table 135. Effect of freezing rate on Instron Newton values for roast beef slices immediately following freezing

Freezing rate, hours to 0°F			
24	48	72	96
91.53 $\pm$ 7.36b	93.34 $\pm$ 7.36b	76.39 $\pm$ 7.36b	128.99 $\pm$ 7.36a

ab Means on the same line with the same letters are not different ( $P > .05$ ); Mean  $\pm$  S.E.



Table 136. Interaction effect of storage time (before freezing, immediately after freezing) and rate of freezing on Instron Newton values for roast beef slices<sup>a</sup>

Evaluation time	Freezing rate, hours to °F			
	24	48	72	96
Before freezing	124.26 $\pm$ 7.78	112.81 $\pm$ 7.78	100.46 $\pm$ 7.78	116.76 $\pm$ 7.78
Immediately following freezing, 1 day	91.53 $\pm$ 7.78	93.34 $\pm$ 7.78	76.39 $\pm$ 7.78	128.99 $\pm$ 7.78

<sup>a</sup>Interaction effect significant ( $P < .05$ ) by analysis of variance, but not by HSD.

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Roasts stored initially at 0°F and finally at +20°F had lower Newton values for slices when roasts were frozen to 0°F in 96 hr (Table 138). This difference was not found for the other three freezing rates. Following twelve months of storage, a significant initial and final storage temperature with freezing rate interaction was noted, but Instron problems at this time prevented full statistical analyses (Table 139).

General information throughout storage for Instron modulus values for roast beef slices is shown in Table 140. Again, no clear trends were evident. Following six months of storage, modulus values were higher for roasts frozen to 0°F in 96 hr when roasts were initially stored at 0°F. Such was not the case when roasts were initially held at -10°F (Table 141). A significant ( $P < .05$ ) interaction for time (six, nine) initial and final storage temperature and freezing rate was found for slice modulus values by analysis of variance, but not by HSD (Table 142). After nine months of storage, however, roasts held initially at -10°F produced lower modulus values than roasts initially stored at 0°F (Table 143).

General information pertaining to Instron fail energy values for slices is shown in Table 144. Values were slightly higher for roasts frozen to 0°F in 96 hr. In contrast to the modulus values (Table 143) following nine months of storage, fail energy values for roasts stored initially at -10°F were higher than those stored at 0°F (Table 145). For roasts initially stored at -10°F and finally stored at +20°F, the 0°F in 48 hr freezing rate generated lower fail energy values for slices than the 0°F in 96 hr freezing rate (Table 146). Following twelve months storage, other storage temperature-freezing rate comparisons did not differ. Also at twelve months of storage (Table 147) for roasts stored initially at -10°F and receiving temperature abuse, the 0°F in 96 hr rate produced much

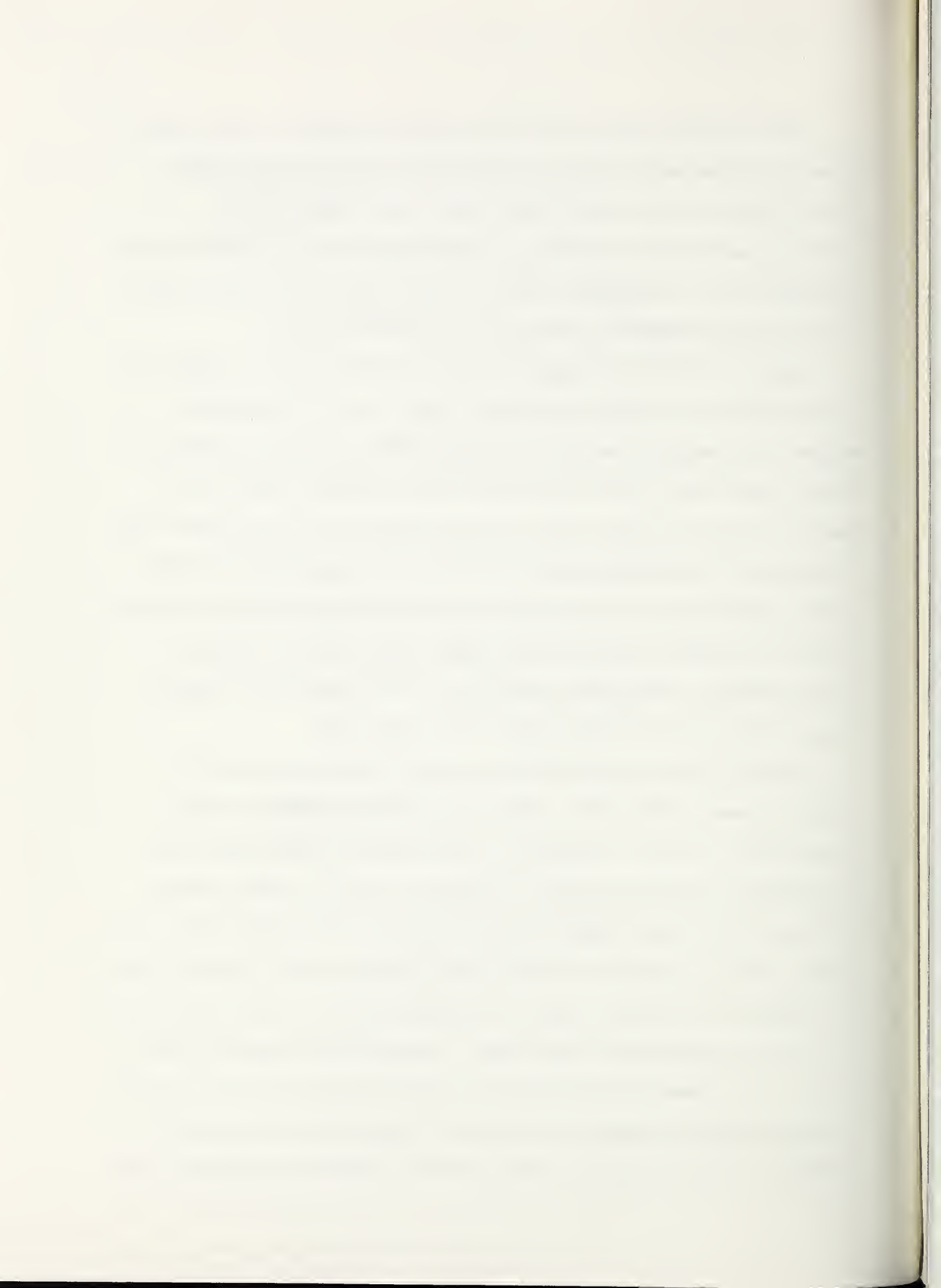




Table 137. Effect of storage time (before freezing, immediately following freezing) on Instron Newton values for roast beef slices

Evaluation time	
Before freezing	Immediately following freezing, 1 day
113.57 $\pm$ 3.89a	97.56 $\pm$ 3.89b

ab Differences between means significant ( $P < .05$ ); Mean  $\pm$  S.E.



Table 138. Interaction effect of storage time (immediately following freezing, six months), initial storage temperature, final storage temperature and rate of freezing on Instron Newton values for roast beef slices

Evaluation time	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F			
			24	48	72	96
Immediately following freezing, 1 day			79.32 + 8.4ab	78.72 + 8.4ab	67.57 + 8.4ab	134.17 + 8.4a
6 months	-10	-10	78.45 + 14.55ab	100.97 + 14.55ab	111.88 + 14.55ab	81.61 + 14.55ab
		0	101.79 + 14.55ab	90.32 + 14.55ab	91.54 + 14.55ab	81.18 + 14.55ab
		20	103.63 + 14.55ab	83.92 + 14.55ab	92.43 + 14.55ab	92.06 + 14.55ab
	0	-10	64.83 + 14.55b	95.03 + 14.55ab	92.81 + 14.55ab	83.76 + 14.55ab
	0	0	86.7 + 14.55ab	96.01 + 14.55ab	105.55 + 14.55ab	73.11 + 14.55ab
	20	20	79.11 + 14.55ab	88.62 + 14.55ab	103.76 + 14.55ab	63.87 + 14.55b

ab Any mean comparison with the same letters is not different ( $P>.05$ ). Mean ± S.E.



Table 139. General table illustrating Instron Newton values for roast beef slices at twelve months storage according to initial storage temperature, final storage temperature and rate of freezing<sup>a</sup>

Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
-10	-10	114.0 + 43.0	91.9 + 27.7	56.6 + 6.2	95.2 + 40.6
	0	93.0 + 31.3	91.8 + 21.7	95.7 + 14.8	114.4 + 51.2
	+20	121.0 + 46.0	78.0 + 22.4	98.2 + 21.7	125.7 + 58.4
0	-10	94.4 + 11.6	96.8 + 10.9	82.9 + 16.6	127.4 + 30.3
	0	83.2 + 23.0	74.9 + 14.3	64.9 + 13.6	107.6 + 36.6
	+20	105.2 + 9.1	87.3 + 16.9	77.6 + 18.1	103.0 + 25.7

<sup>a</sup>No statistical analyses possible due to instrumental problem for twelve month stored roasts initially stored at -10°F and frozen to 0°F in 72 h. Mean + S.D.



Table 140. General table illustrating the Instron modulus values for roast beef slices throughout storage times and according to final storage temperature and rate of freezing - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rates, hours to 0°F			
		24	48	72	96
Before freezing		103.97 + 26.92	94.84 + 21.48	106.03 + 18.52	108.90 + 29.6
Immediately after freezing, 1 day		98.48 + 19.94	102.30 + 20.37	99.69 + 20.01	103.31 + 21.12
6 months	-10T	101.13 + 19.74	99.86 + 13.14	95.15 + 17.12	111.97 + 21.9
	0T	110.91 + 17.64	100.07 + 20.38	80.82 + 10.99	116.4 + 17.82
	20T	93.72 + 16.0	96.45 + 18.22	92.60 + 14.53	98.30 + 16.09
9 months	-10T	110.84 + 11.42	91.66 + 16.67	88.52 + 17.77	121.26 + 16.78
	0T	93.48 + 19.85	90.73 + 19.43	96.74 + 16.35	103.68 + 29.84
	20T	104.25 + 25.51	87.07 + 12.36	93.93 + 22.57	94.15 + 18.82
12 months	-10T	113.48 + 15.69	101.40 + 27.77	86.50 + 17.35	98.25 + 21.70
	0T	105.48 + 26.35	111.85 + 19.40	93.17 + 30.48	87.01 + 13.90
	20T	118.26 + 20.35	115.61 + 32.38	92.7 + 14.3	91.23 + 16.94
	20N	107.04 + 22.96	81.62 + 13.48	104.90 + 20.2	87.70 + 19.72

<sup>a</sup> Mean + S.D. T = temperature abused; N = Not temperature abused.





Table 141. Interaction effect of initial storage temperature and rate of freezing on Instron modulus values for roast beef slices following six months storage

Initial storage temperature, °F	Freezing rates, hours to 0°F			
	24	48	72	96
-10	104.16 $\pm$ 4.18ab	96.93 $\pm$ 4.18b	94.38 $\pm$ 4.18b	97.16 $\pm$ 4.18b
0	99.69 $\pm$ 4.18b	100.66 $\pm$ 4.18ab	84.68 $\pm$ 4.18b	120.62 $\pm$ 4.18a

ab Any mean comparison with the same letter is not different ( $P > .05$ ). Mean  $\pm$  S.E.



Table 142. Interaction effect of storage time (six, nine months) initial storage temperature, final storage temperature and rate of freezing on Instron modulus values for roast beef slices<sup>a</sup>

Evaluation time, months	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F			
			24	48	72	96
6	-10	-10	93.21 ± 7.91	105.08 ± 7.91	107.32 ± 7.91	96.56 ± 7.91
		0	115.77 ± 7.91	96.06 ± 7.91	78.58 ± 7.91	105.30 ± 7.91
	0	20	103.50 ± 7.91	89.65 ± 7.91	97.23 ± 7.91	89.61 ± 7.91
		-10	109.06 ± 7.91	94.65 ± 7.91	82.98 ± 7.91	127.37 ± 7.91
		0	106.06 ± 7.91	104.08 ± 7.91	83.07 ± 7.91	127.50 ± 7.91
9	-10	20	83.95 ± 7.91	103.26 ± 7.91	87.97 ± 7.91	106.99 ± 7.91
		-10	112.38 ± 7.91	81.42 ± 7.91	84.60 ± 7.91	113.23 ± 7.91
	0	0	92.41 ± 7.91	84.19 ± 7.91	96.98 ± 7.91	102.89 ± 7.91
		20	82.82 ± 7.91	89.91 ± 7.91	80.18 ± 7.91	91.40 ± 7.91
		-10	109.30 ± 7.91	101.91 ± 7.91	92.44 ± 7.91	129.29 ± 7.91
		0	94.55 ± 7.91	97.27 ± 7.91	96.49 ± 7.91	104.47 ± 7.91
		20	125.68 ± 7.91	84.23 ± 7.91	107.68 ± 7.91	96.90 ± 7.91

<sup>a</sup> Interaction significant (P<.05) by analysis of variances, but not by HSD. Mean ± S.E.



Table 143. Effect of initial storage temperature on Instron modulus values for roast beef slices following nine months of storage

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<u>Initial storage temperature, °F</u>	
<u>-10</u>	<u>0</u>
92.7 $\pm$ 2.8b	103.3 $\pm$ 2.8a

---

ab Difference between means significant ( $P < .05$ ).



Table 144. General table illustrating Instron fail energy values for roast beef slices through storage and according to final storage temperature and rate of freezing - no statistical analysis<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		2.16 ± .63	2.27 ± .70	2.10 ± .60	2.39 ± .62
Immediately after freezing, 1 day		2.33 ± .67	1.99 ± .62	2.10 ± .79	2.35 ± .78
6 months	-10T	1.92 ± .36	2.59 ± .62	2.23 ± .42	2.69 ± .63
	0T	2.36 ± .37	2.73 ± 1.02	2.41 ± .90	2.29 ± .78
	20T	2.15 ± .54	2.01 ± .33	2.42 ± .90	2.11 ± .38
9 months	-10T	2.46 ± .56	2.06 ± .65	2.61 ± .64	2.60 ± .65
	0T	2.56 ± .77	2.26 ± .54	2.55 ± .76	2.48 ± .72
	20T	2.76 ± .63	2.33 ± .77	2.67 ± .67	2.69 ± .97
12 months	-10T	2.38 ± .51	2.46 ± .63	2.27 ± 1.09	2.60 ± .42
	0T	2.38 ± .53	1.81 ± .40	2.46 ± .52	2.85 ± .75
	20T	2.53 ± .63	1.90 ± .76	2.24 ± .39	3.00 ± .70
	20N	1.82 ± .36	2.56 ± .47	2.21 ± .64	3.42 ± .73

<sup>a</sup> Mean ± S.D., T = temperature abused; N = not temperature abused





Table 145. Effect of initial storage temperature on Instron fail energy values for roast beef slices following nine months of storage

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<u>Initial storage temperature, °F</u>	
<u>-10</u>	<u>0</u>
2.52 $\pm$ .13a	2.48 $\pm$ .13b

---

ab Difference between means significant ( $P < .05$ ). Mean  $\pm$  S.E.

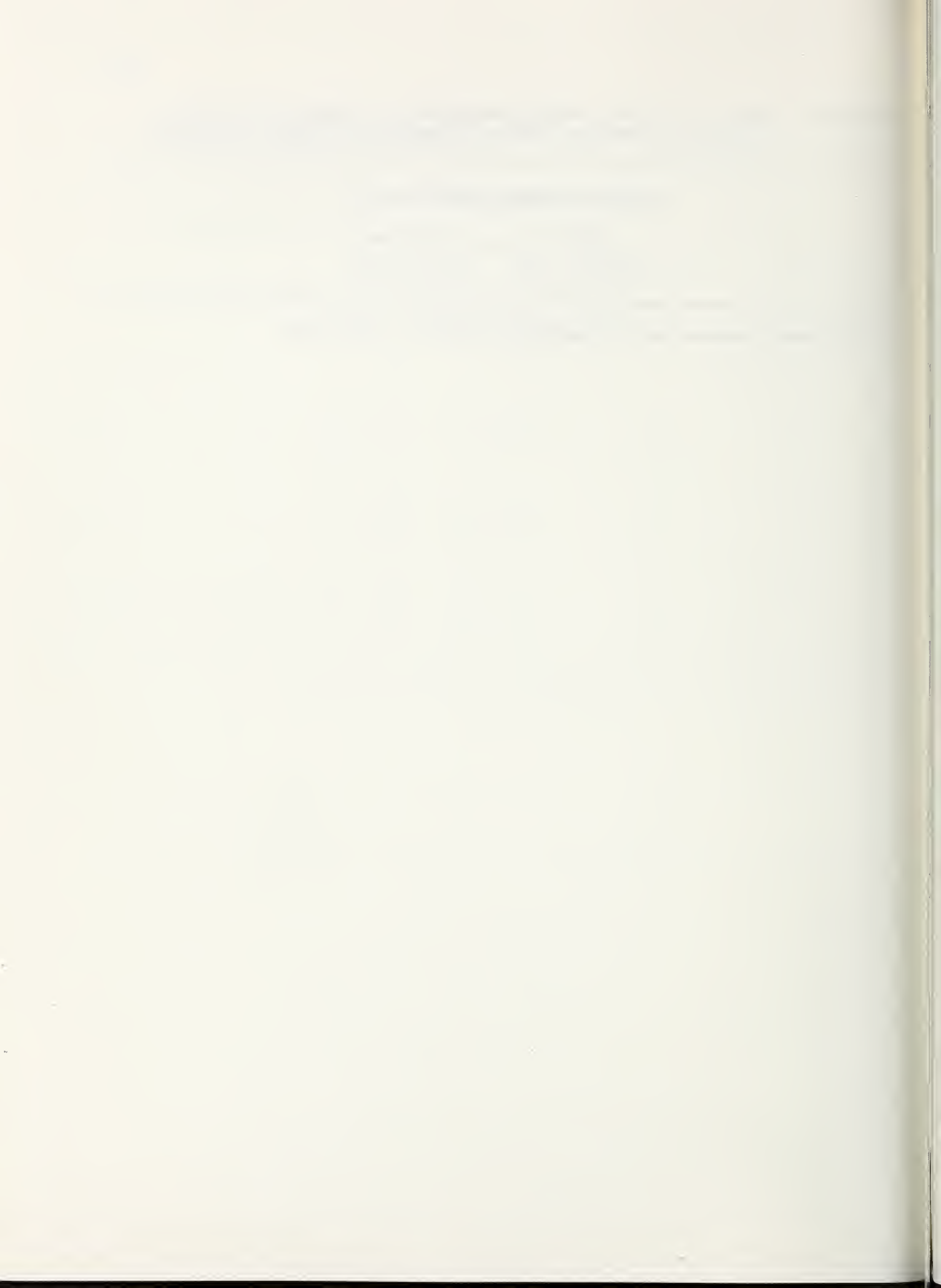


Table 146. Interaction effect of initial storage temperature, final storage temperature and rate of freezing on Instron fall energy values for roast beef slices following twelve months of storage

Initial Storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
-10	-10	2.14 + .29abc	2.58 + .29abc	1.44 + .29bc	2.57 + .29abc
	0	2.13 + .29abc	1.78 + .29abc	2.34 + .29abc	2.79 + .29abc
	20	2.13 + .29abc	1.26 + .29c	2.18 + .29abc	3.46 + .29a
0	-10	2.62 + .29abc	2.33 + .29abc	3.10 + .29ab	2.62 + .29abc
	0	2.63 + .29abc	1.85 + .29abc	2.57 + .29abc	2.90 + .29abc
	20	2.92 + .29abc	2.54 + .29abc	2.30 + .29abc	2.54 + .29abc

abc Any mean comparison with the same letters is not different ( $P > .05$ ).

Mean + S.E.



Table 147. Interaction effect of temperature abuse, initial storage temperature and rate of freezing on Instron fail energy values for roast beef slices following twelve months of storage

Temperature abuse	Initial storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
T	-10	2.13 + .31abcd	1.26 + .31d	2.18 + .31abcd	3.46 + .31ab
	0	2.92 + .31abcd	2.54 + .31abcd	2.30 + .31abcd	2.54 + .31abcd
N	-10	2.01 + .31abcd	2.79 + .31abcd	1.85 + .31bcd	3.12 + .31abc
	0	1.63 + .31cd	2.34 + .31abcd	2.57 + .31abcd	3.72 + .31a

abcd Any mean comparison with the same letter is not different ( $P > .05$ ). Mean + S.E.  
 T = temperature abused; N = Not temperature abused.



higher fail energy values than the 0°F in 48 hr rate. For nonabused roasts, initially stored at 0°F, the 0°F in 96 hr freezing rate generated higher fail energy values than the 0°F in 24 hr rate.

Many differences were detected in the storage time (immediately after freezing, twelve months), initial and final storage temperature and freezing rate interaction for fail energy values for slices (Table 148). Many of the differences (although not consistent in direction) were between temperature and nontemperature abused roasts. A significant ( $P < .05$ ) interaction involving storage time (nine, twelve months) initial storage temperature and freezing rate was found for Instron fail energy values for slices by analyses of variance, but not by HSD procedures (Table 149).

The next section of this report deals with the many forms in which weight loss was expressed throughout the project. The values given in Table 150 relate to the total project loss involved for roasts from before freezing until after cooling of cooked roasts. Obviously, for roasts not subjected to freezing (before the project), this weight loss is simply that weight lost in cooking and cooling and thus is much less. Increases in storage time did not greatly change this "total project loss," although roasts stored at +20°F appeared to sustain more loss.

The values given in Table 151 indicate there were some differences in total loss among each week's selection of roasts (different freezing rates). Following nine months of storage, for roasts initially stored at -10°F and frozen to 0°F in 48 hr and for roasts initially stored at 0°F and frozen to 0°F in 24 hr; +20°F final storage produced more total loss than roasts stored at 0°F (Table 152). Dropping out the 0°F in 72 hr rate (which then enabled the inclusion of -10°F final storage temperature) did not change these findings (Table 153).





Table 148. Interaction effect of storage time (immediately following freezing, twelve months) initial storage temperature, final storage temperature and rate of freezing on Instron fall energy values for roast beef slices

Evaluation time	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F			
			24	48	72	96
Immediately after freezing, 1 day			2.33 ± .16defg	1.99 ± .16efgh	2.10 ± .16efgh	2.35 ± .16defg
	-10	20T	2.31 ± .43defgh	1.79 ± .43h	2.32 ± .43defgh	3.54 ± .43b
		20N	2.46 ± .43cdef	2.53 ± .43cde	2.22 ± .43defgh	2.95 ± .43c
12 months	0	20T	2.69 ± .43cd	2.19 ± .43efgh	2.41 ± .43defg	1.88 ± .43gh
		20N	1.23 ± .43i	2.41 ± .43defg	1.94 ± .43fgh	4.47 ± .43a

abcdefgh Any mean comparison with different letters is different ( $P < .05$ ).  
 Mean + S.E., 't' = temperature abused; N = not temperature abused.



Table 149. Interaction effect of storage time (nine, twelve months) initial storage temperature and rate of freezing on Instron fail energy values for roast beef slices<sup>a</sup>

Evaluation time, months	Initial storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
9	-10	2.79 $\pm$ .23	2.38 $\pm$ .23	2.66 $\pm$ .23	2.27 $\pm$ .23
	0	2.41 $\pm$ .23	2.05 $\pm$ .23	2.56 $\pm$ .23	2.91 $\pm$ .23
12	-10	2.13 $\pm$ .23	1.87 $\pm$ .23	1.99 $\pm$ .23	2.94 $\pm$ .23
	0	2.72 $\pm$ .23	2.24 $\pm$ .23	2.66 $\pm$ .23	2.69 $\pm$ .23

<sup>a</sup>Interaction effects significant ( $P < .05$ ) by analysis of variance, but not by HSD. Mean  $\pm$  S.E.



Table 150. General table illustrating the percent change in weight for beef roasts from just before freezing until after cooling of cooked roasts throughout storage and according to final storage temperature and rate of freezing - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		-30.26 + 1.62	-28.23 + 2.37	-28.92 + 2.52	-31.89 + 2.24
Immediately following freezing, 1 day		-34.62 + 1.68	-33.79 + 3.45	-34.01 + 2.29	-35.93 + 1.14
6 months	-10T	-32.58 + 3.58	-37.13 + 2.43	-34.65 + 2.42	-30.46 + 1.81
	0T	-35.59 + .38	-31.87 + 4.66	-34.16 + 3.02	-30.73 + 3.62
	20T	-35.34 + 1.65	-32.95 + 7.53	-33.6 + 2.34	-34.37 + 3.61
9 months	-10T	-31.72 + 3.86	-32.13 + 1.20	-36.49 + 1.20	-31.87 + 2.88
	0T	-32.37 + 3.83	-31.23 + 3.65	-33.25 + 2.77	-34.22 + 1.41
	20T	-36.50 + 1.51	-33.19 + 2.10	-37.66 + 1.54	-35.74 + 2.87
12 months	-10T	-33.90 + 2.86	-29.27 + 1.65	-33.47 + 1.31	-32.96 + 2.49
	0T	-32.62 + 1.75	-32.51 + 2.85	-34.98 + 2.63	-32.84 + 1.16
	20T	-36.74 + 2.21	-35.19 + 2.32	-35.76 + 1.34	-34.64 + 1.61
	20N	-34.17 + 2.71	-30.45 + 3.05	-33.41 + 4.10	-34.23 + 5.42

<sup>a</sup>Mean + S.D. T = temperature abused, N = not temperature abused.



Table 151. Effect of freezing rate on percent change in weight from just before freezing until after cooling of cooked beef roasts for roasts not frozen just before freezing

<u>Final rate, hours to 0°F</u>			
<u>24</u>	<u>48</u>	<u>72</u>	<u>96</u>
-30.26 $\pm$ .77ab	-28.23 $\pm$ 1.09b	-28.92 $\pm$ .77ab	-31.89 $\pm$ .89a

ab Means on the same line with the same letters are not different ( $P < .05$ ).  
Mean  $\pm$  S.E.

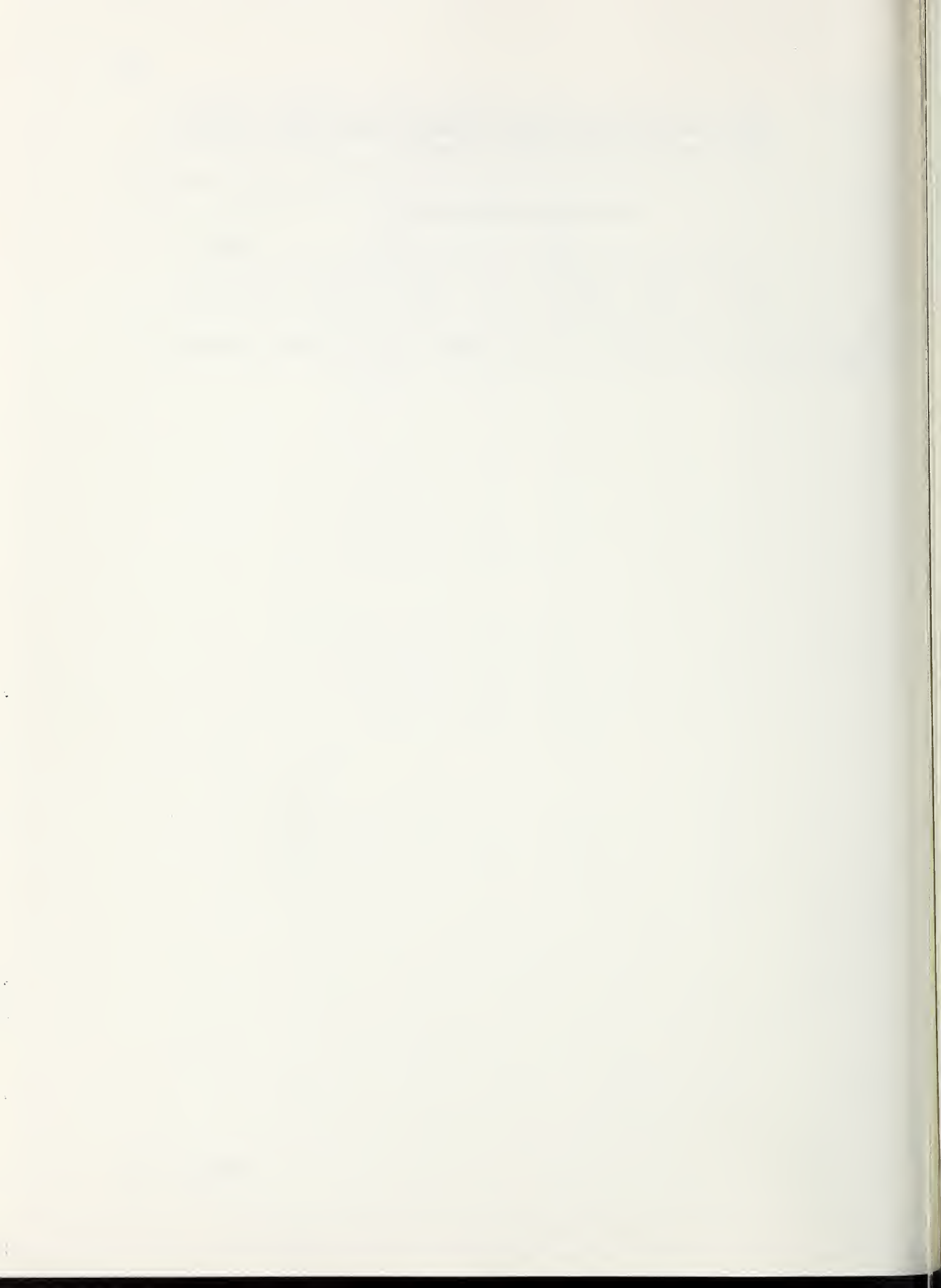




Table 152. Interaction effect of initial storage temperature, final storage temperature and rate of freezing on percent change in weight of beef roasts from just before freezing until after cooling of cooked roasts following nine months storage

Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
-10	0	-35.67 + 1.09abc	-28.08 + 1.09c	-34.91 + 1.09abc	-33.22 + 1.09abc
	20	-35.68 ± 1.09abc	-33.85 ± 1.09abc	-38.28 ± 1.09a	-34.87 ± 1.09abc
0	0	-29.05 + 1.09bc	-34.38 + 1.09abc	-31.6 ± 1.09abc	-35.22 + 1.09abc
	20	-37.32 ± 1.09a	-32.54 ± 1.09abc	-37.05 ± 1.09a	-36.61 ± 1.09ab

abc Any mean comparison with the same letters is not different ( $P>.05$ ). Mean ± S.E.



Table 153. Interaction effect of initial storage temperature, final storage temperature and rate of freezing on percent change in weight of beef roasts from just before freezing until after cooling cooked roasts following nine months storage

Initial storage temperature, °F	Final storage temperature, °F	Freezing Rate, hours to 0°F		
		24	48	96
-10	-10	-34.23 ± 1.39ab	-32.35 ± 1.39ab	-30.34 ± 1.39ab
	0	-35.67 ± 1.39ab	-28.08 ± 1.39b	-33.22 ± 1.39ab
	+20	-35.68 ± 1.39ab	-33.85 ± 1.39ab	-34.87 ± 1.39ab
0	-10	-29.21 ± 1.39ab	-31.9 ± 1.39ab	-33.4 ± 1.39ab
	0	-29.05 ± 1.39ab	-34.38 ± 1.39ab	-35.22 ± 1.39ab
	+20	-37.32 ± 1.39a	-32.54 ± 1.39ab	-36.61 ± 1.39a

ab Any mean comparisons with the same letters are not different ( $P > .05$ ). Mean ± S.E.

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Following twelve months of storage, roasts finally stored at +20°F underwent more weight loss from before freezing until after cooling of cooked roasts than what occurred for the other two temperatures (Table 154). As noted earlier, the process of freezing itself substantially increased "total project losses" (Table 155). However, losses at nine months were less than those found immediately following freezing. The same situation also applied after twelve months storage (Table 156).

An interaction involving six-nine months of storage with other variables was detected by analysis of variance, but not by HSD mean separation (Table 157). In breaking out all the treatment combinations inherent at nine months storage, it was found that none had less total loss than that noted immediately following freezing (Table 158). The same also applied at twelve months of storage (Table 159, 160).

The next table presents simply the percent change in weight as a result of freezing with no storage. Table 161 provides the general information regarding this trait and shows in most cases that the roasts actually gained in weight as a result of freezing.

General information regarding strictly the weight loss or gain as a result of freezer storage is given in Table 162. It is obvious that the advancements in storage time and the use of +20°F final storage temperature produced greater weight loss during storage; however, in many cases the mean values are < 0.02% loss. Roasts frozen to 0°F in 72 hr sustained more weight loss than roasts frozen to 0°F in 24 hr if initial storage was at -10°F following six months storage. This difference was not found for roasts subjected to 0°F initial storage (Table 163). The major logical factor responsible for the initial-final storage temperature-freezing rate interaction at nine months storage was the substantially greater storage



Table 154. Effect of final storage temperature on percent change in weight from just before freezing until after cooling of cooked beef roasts following twelve months storage

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<u>Final storage temperature, °F</u>		
<u>-10</u>	<u>0</u>	<u>20</u>
-32.40 $\pm$ .54b	-33.24 $\pm$ .54b	-35.58 $\pm$ .59a

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ab Means on the same line with different letters are different ( $P < .05$ ).  
Mean  $\pm$  S.E.





Table 155. Effect of various storage time comparisons on percent change in weight from just before freezing until after cooling of cooked beef roasts

<u>Evaluation time</u>	
<u>Before freezing</u>	<u>Immediately following freezing, 1 day</u>
-29.88 ± .52b	-34.59 ± .42a
<u>Immediately following freezing, 1 day</u>	<u>9 months<sup>c</sup></u>
-34.38 ± .69a	-33.21 ± .69b
<u>Immediately following freezing, 1 day</u>	<u>9 months<sup>d</sup></u>
-34.48 ± .80a	-34.29 ± .80b

ab Differences between means significant ( $P < .05$ ). Mean ± S.E.

<sup>c</sup>Does not include 0°F in 72 hr freezing rate.

<sup>d</sup>Does not include -10°F final storage temperature.



Table 156. Effect of storage time (immediately following freezing, twelve months) on percent change in weight of beef roasts from just before freezing until after cooling of cooked roasts

Evaluation Time	
Immediately after freezing, 1 day	12 months
-34.47 $\pm$ .65a	-33.71 $\pm$ .65b

ab Difference between means significant ( $P < .05$ ).  
Mean  $\pm$  S.E. Includes only temperature abused product.



Table 157. Interaction effect of storage time (six, nine months), initial storage temperature, final storage temperature and freezing rate on percent change in weight from just before freezing until after cooling of cooked beef roasts<sup>a</sup>

Evaluation time, months	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to °F			
			24	48	72	96
6	-10	0	-35.40 + 1.96	-33.41 + 1.96	-33.19 + 1.96	-33.21 + 1.96
		20	-35.68 + 1.96	-34.32 + 1.96	-34.71 + 1.96	-31.31 + 1.96
	0	0	-35.77 + 1.96	-30.34 + 1.96	-35.12 + 1.96	-28.26 + 1.96
		20	-35.00 + 1.96	-31.85 + 3.39	-32.49 + 1.96	-37.44 + 1.96
9	-10	0	-35.67 + 1.96	-28.08 + 1.96	-39.79 + 3.39	-33.22 + 1.96
		20	-35.68 + 1.96	-33.85 + 1.96	-38.28 + 1.96	-34.87 + 1.96
	0	0	-29.05 + 1.96	-34.38 + 1.96	-31.6 + 1.96	-35.22 + 1.96
		20	-37.32 + 1.96	-32.54 + 1.96	-37.05 + 1.96	-36.61 + 1.96

<sup>a</sup>Interaction significant ( $P < .05$ ) by analysis of variance, but not by HSD. Mean + S.E.



Table 158. Effect of storage time (immediately following freezing, nine months) on percent change in weight from just before freezing until after cooling of cooked beef roasts

		9 months storage		
Immediately following freezing, 1 day	Initial storage temperature, °F =	-10		0
	Final storage Temperature, °F =	-10	20	0
-34.38 ± .60ab		-32.12 ± 1.04ab	-32.14 ± 1.04ab	-34.62 ± 1.04ab
			-31.69 ± 1.04b	-33.06 ± 1.04ab
				-35.67 ± 1.04a

ab Means on the same line with the same letters are not different (P>.05). Mean ± S.E. Does not include 0°F in 72 hr freezing rate.

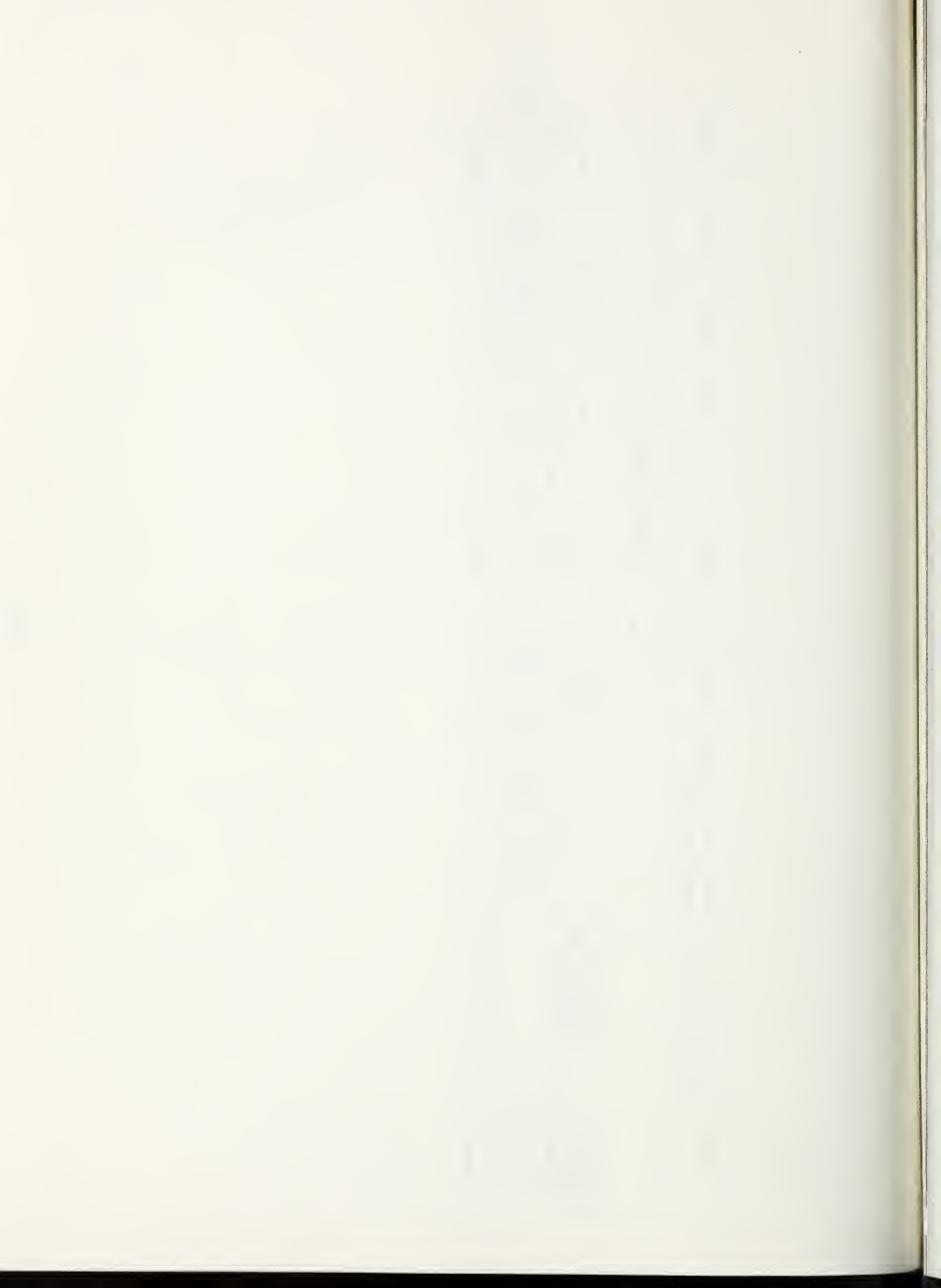




Table 159. Effect of storage time (immediately following freezing, nine months) on percent change in weight from just before freezing until after cooling of cooked beef roasts

		12 months storage	
Immediately following freezing, 1 day	Initial storage temperature, °F =	-10	0
	Final storage Temperature, °F =	20	20
	-34.48 ± .51ab	-32.84 ± .98b -35.44 ± .88ab	-32.79 ± .88b -36.11 ± .88a

ab Means on the same line with the same letters are not different ( $P > .05$ ). Mean ± S.E. Does not include -10°F final storage temperature.



Table 160. Effect of storage time (immediately following freezing, 12 months storage) on percent change in weight of beef roasts from just before freezing until just after cooling cooked roasts

		12 months			
Initial storage temperature, °F =		-10		0	
Final storage temperature, °F =		-10		0	
Immediately after freezing, 1 day		-10	+20	-10	+20
-34.48 ± .55ab		-32.82 ± .96ab	-33.05 ± .96ab	-31.98 ± .96b	-33.42 ± .96ab
			-35.64 ± 1.06a		-35.35 ± .96ab

ab Means on the same line with the same letters are not different ( $P > .05$ ). Mean ± S.E. Includes only temperature abused product.



Table 161. General table illustrating the percent change in weight from just before until just after freezing for beef roasts throughout storage and according to final storage temperature and rate of freezing - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing					
Immediately following freezing, 1 day					
6 months	-10T	.033 + .044	-.012 + .065	.140 + .220	.010 + .036
	0T	.040 + .015	.043 + .034	.070 + .082	.037 + .030
	20T	.034 + .035	.028 + .022	.050 + .052	.048 + .043
9 months	-10T	.025 + .023	.020 + .028	.049 + .067	.035 + .027
	0T	.036 + .022	.043 + .052	.042 + .039	.05 + .035
	20T	.014 + .032	.026 + .018	.084 + .17	.046 + .020
12 months	-10T	.024 + .068	.023 + .019	.042 + .046	.037 + .037
	0T	.024 + .062	.013 + .024	-.106 + .310	.038 + .034
	20T	.039 + .032	.023 + .048	.079 + .087	.036 + .031
	20T	.045 + .021	.027 + .017	.060 + .069	.051 + .031
	20N	.028 + .056	.0002 + .039	.052 + .058	.024 + .014

<sup>a</sup> Mean + S.D. T = temperature abused, N = not temperature abused.



Table 162. General table illustrating the percent change in weight from just after freezing for beef roasts throughout storage and according to final storage temperature and freezing rate - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F							
		24	48	72	96				
Before freezing									
Immediately following freezing, 1 day									
6 months	-10T	.046 +	.025 -	.15 +	.082	-.080 +	.088	-.015 +	.019
	0T	-.087 +	.095 -	-.064 +	.013	-.095 +	.054	-.064 +	.110
	20T	-.120 +	.058 -	-.152 +	.110	-.232 +	.164	-.086 +	.020
9 months	-10T	.034 +	.039 -	-.035 +	.068	.014 +	.042	.000019 +	.060
	0T	.019 +	.053 -	-.048 +	.037	-.0023 +	.135	.076 +	.170
	20T	-.150 +	.104 -	-.231 +	.074	-.073 +	.084	-.120 +	.090
12 months	-10T	-.150 +	.154 -	.036 +	.044	-.048 +	.070	.001 +	.082
	0T	-.130 +	.058 -	-.060 +	.121	-.204 +	.150	-.033 +	.098
	20T	-.296 +	.049 -	-.265 +	.076	-.260 +	.110	-.206 +	.160
	20N	-.280 +	.113 -	-.240 +	.145	-.217 +	.150	-.142 +	.140

<sup>a</sup>Mean + S.D. T = temperature abused, N = not temperature abused.





Table 163. Interaction effect of initial storage temperature and freezing rate on percent change in weight for beef roasts from just after freezing until after six months storage.

Initial storage temperature, °F	Freezing rate, hours to 0°F			
	24	48	72	96
-10	-0.042 + <u>  </u>	-0.15 + <u>  </u>	-0.19 + <u>  </u>	-0.078 + <u>  </u>
0	-0.12 + <u>  </u>	-0.099 + <u>  </u>	-0.08 + <u>  </u>	-0.031 + <u>  </u>

ab Any mean comparison with the same letters is not different ( $P > .05$ ) Mean  $\pm$  S.E.



loss for roasts frozen to 0°F in 24 hr, initially stored at 0°F and finally stored at +20°F vs the same initial temperature and freezing rate, but the 0°F final storage temperature (Table 164). After both six and nine months storage, +20°F final temperature resulted in higher ( $P < .05$ ) storage losses than the other two temperatures (Table 165). Six months storage produced more loss than nine months storage (Table 166). In comparing nine vs twelve months of storage (Table 167), twelve months produced more weight loss only if roasts were frozen to 0°F in either 24 or 72 hr.

Combining the losses during freezing with those obtained during storage is shown in the next series of tables. Since more of the loss occurred during storage than freezing, these data in combined form reflect more of the effect of storage time (Table 168). The slower freezing rates (0°F in 72, 96 hr) actually had a gain in patty weight during this interval compared to the faster rates (0°F in 24, 48 hr - Table 169). After six, nine and twelve months storage, +20°F storage produced more weight loss than the other two temperatures (Table 170). When weight losses from before freezing until after storage were determined at six months storage, roasts frozen to 0°F in 48 or 72 hr underwent more weight loss than roasts frozen to 0°F in 96 hr if roasts were initially stored at -10°F (Table 171). This trend was not found for roasts initially stored at 0°F.

A complex four-way interaction involving time (six, nine months), initial and final storage temperatures and freezing rate is shown in Table 172. The interaction seems to center largely around the extent of weight loss for roasts stored at +20°F. For some treatment combinations, the weight loss was extensive if +20°F was used, but for some others the loss was not large. No differences in weight loss was found following nine months storage between 0°F in 24 and 0°F in 48 hr freezing rates, while after twelve months 0°F in 24 hr rate sustained more loss (Table 173).



Table 164. Interaction effect of initial storage temperature, final storage temperature, and freezing rate on percent change in weight of beef roasts from just after freezing until after nine months storage

Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
-10	-10	+ .057 + .044c	-.041 + .044abc	+ .009 + .044bc	-.016 + .044abc
	0	-.024 + .044abc	-.022 + .044abc	-.088 + .044abc	+ .180 + .044abc
	20	-.075 + .044abc	-.18 + .044abc	-.073 + .044abc	-.160 + .044abc
0	-10	+ .010 + .044bc	-.029 + .044abc	-.019 + .044abc	+ .016 + .044bc
	0	+ .062 + .044c	-.074 + .044abc	+ .083 + .044c	-.026 + .070abc
	20	-.23 + .044ab	-.282 + .044a	-.074 + .044abc	-.081 + .044abc

abc Any mean comparison with the same letters is not different ( $P > .05$ ). Mean ± S.E.



Table 165. Effect of final storage temperature on percent change in weight for beef roasts from just after freezing until after various storage periods

Evaluation time, months	Final Storage Temperature, °F		
	-10	0	+20
6	$-.074 \pm .017b$	$-.077 \pm .017b$	$-.15 \pm .017a$
12	$-.040 \pm .019b$	$-.110 \pm .023b$	$-.260 \pm .019a$

ab Means on the same line with different letters are different ( $P < .05$ ). Mean  $\pm$  S.E.





Table 166. Effect of storage time (six, nine months) on percent change in weight for beef roasts from just after freezing until after storage

<u>Evaluation Time, months</u>	
6	9
$-.099 \pm .011a$	$-.042 \pm .011b$

ab Difference between means significant ( $P < .05$ ).  
Mean  $\pm$  S.E.



Table 167. Interaction effect of storage time (nine, twelve months), and freezing rate on percent change in weight for beef roasts from just after freezing until after storage

Evaluation time, months	Freezing Rate, hours to 0°F			
	24	48	72	96
9	-.034 $\pm$ .021c	-.10 $\pm$ .021abc	-.02 $\pm$ .021c	-.015 $\pm$ .023c
12	-.19 $\pm$ .021a	-.11 $\pm$ .023abc	-.17 $\pm$ .021ab	-.078 $\pm$ .023bc

abc Any mean comparison with different letters is different ( $P < .05$ ).  
Mean  $\pm$  S.E.



Table 168. General table illustrating the percent change in weight during storage for beef roasts from just before freezing until after storage and according to final storage temperature and rate of freezing - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing					
Immediately following freezing, 1 day					
6 months	-10T	-.006 + .020	-.11 + .102	-.009 + .052	.022 + .032
	0T	-.053 + .112	-.036 + .028	-.045 + .017	-.016 + .076
	20T	-.093 + .064	-.131 + .124	-.183 + .170	-.051 + .011
9 months	-10T	.069 + .038	.0083 + .017	.056 + .024	.050 + .041
	0T	.033 + .036	-.021 + .030	.081 + .082	.125 + .172
	20T	-.130 + .110	-.021 + .065	-.032 + .052	-.082 + .066
12 months	-10T	-.124 + .125	.050 + .063	-.154 + .252	.039 + .063
	0T	-.090 + .069	-.057 + .095	-.125 + .092	-.0004 + .075
	20T	-.252 + .065	-.238 + .090	-.200 + .041	-.155 + .150
	20N	-.250 + .130	-.240 + .163	-.165 + .093	-.120 + .143

<sup>a</sup> Mean + S.D. T = temperature abused, N = not temperature abused.



Table 169. Effect of freezing rate on percent change in weight for beef roasts from just before freezing until after nine months storage

Freezing Rate, hours to 0°F			
24	48	72	96
-0.0095 ± .02a	-0.074 ± .02a	+0.035 ± .20b	+0.031 ± .2b

ab Means on the same line with different letters are different ( $P < .05$ ).  
Mean ± S.E.





Table 170. Effect of final storage temperature on percent change in weight for beef roasts from just before freezing until after various storage periods

Evaluation time, months	Final storage temperature, °F		
	-10	0	20
6	$-.026 \pm .018b$	$-.037 \pm .018b$	$-.114 \pm .018a$
9	$+.046 \pm .018b$	$+.054 \pm .018b$	$-.110 \pm .018a$
12	$-.047 \pm .032b$	$-.068 \pm .037b$	$-.21 \pm .032a$

ab Means on the same line with different letters are different ( $P < .05$ ).  
Mean  $\pm$  S.E.



Table 171. Interaction effect of initial storage temperature and freezing rate on percent change in weight from just before freezing until after six months storage for beef roasts

Initial storage temperature, °F	Freezing rate, hours to 0°F			
	24	48	72	96
-10	-.0089 ± .029ab	-.14 ± .029a	-.14 ± .029a	.008 ± .029b
0	-.092 ± .029ab	-.05 ± .029ab	-.014 ± .029ab	-.038 ± .029ab

ab Any mean comparison with the same letters is not different ( $P > .05$ ) Mean ± S.E.



Table 172. Interaction effect of storage time (six, nine months), initial storage temperature, final storage temperature and freezing rate on percent change in weight from just before freezing until after storage

Evaluation time, months	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to °F							
			24.	48	72	96				
6	-10	-10	-.0022	+.048bcd	-.17	+.048abcd	-.053	+.048abcd	+.0015	+.048bcd
		0	+.026	+.048bcd	-.040	+.048abcd	-.058	+.048abcd	-.056	+.048abcd
		+20	-.051	+.048abcd	-.194	+.048abcd	-.32	+.048a	-.058	+.048abcd
	0	-10	-.010	+.048bcd	-.048	+.048abcd	+.035	+.048bcd	+.043	+.048bcd
		0	-.132	+.048abcd	-.033	+.048abcd	-.032	+.048abcd	+.025	+.048bcd
		+20	-.134	+.048abcd	-.069	+.048abcd	-.044	+.048abcd	-.043	+.048abcd
9	-10	-10	+.101	+.048d	+.012	+.048bcd	-.040	+.048bcd	+.028	+.048bcd
		0	+.0028	+.048bcd	-.0009	+.048bcd	-.080	+.048cd	-.21	+.048abc
		+20	-.036	+.048abcd	-.170	+.048abcd	-.042	+.048abcd	-.13	+.048abcd
	0	-10	+.037	+.048bcd	+.004	+.048bcd	-.071	+.048cd	+.072	+.048cd
		0	+.063	+.048cd	-.042	+.048abcd	-.083	+.048cd	+.042	+.048bcd
		+20	-.225	+.048abc	-.250	+.048ab	-.023	+.048abcd	-.038	+.048abcd

abcd Any mean comparisons with the same letters are not different ( $P > .05$ ). Mean  $\pm$  S.E.



Table 173. Interaction effect of storage time (nine, twelve months) and freezing rate on percent change in weight of beef roasts from before freezing until after storage

Evaluation time, months	Freezing Rate, hours to 0°F			
	24	48	72	96
9	-.0095 $\pm$ .028ab	-.074 $\pm$ .028ab	+.035 $\pm$ .028b	+.031 $\pm$ .028b
12	-.15 $\pm$ .028a	-.095 $\pm$ .032b	-.16 $\pm$ .028a	-.034 $\pm$ .032ab

ab Any mean comparison with different letters are different ( $P < .05$ ).  
Mean  $\pm$  S.E.





Values for percent thaw loss are given next. To some extent, the thaw losses are larger as a result of longer storage times and the use of +20°F storage temperature (Table 174). At both nine and twelve months, roasts frozen to 0°F in 48 hr had lower thaw losses, especially when compared to roasts frozen to 0°F in 96 hr (Table 175). At both nine and twelve months, the use of +20°F final storage temperature resulted in more thaw loss than -10°F temperature (Table 176). It is somewhat surprising to see higher temperatures of storage and longer storage times producing more thaw loss, since it would seem those conditions would result in more losses during storage (which they did) that would normally then not be lost in thawing.

The next set of tables depicts the weight loss from before freezing until after thawing. Since this range encompasses some previous information, the greater reduction in weight as a result of additional storage and the +20°F temperature was to be expected (Table 177). Following both nine and twelve months of storage, the use of +20°F final temperature created more loss than the -10°F temperature (Table 178). This form of loss was less at nine months for roasts frozen to 0°F in 48 hr vs those frozen to 0°F in either 72 or 96 hr (Table 179). Losses from before freezing until after thawing were greater following six, nine and twelve months compared to immediately following freezing (Tables 180, 181). There is some indication at nine months and twelve months storage that -10°F initial storage did not increase these losses as much as 0°F initial storage (Tables 182, 183). Roasts initially stored at 0°F and receiving temperature abuse were not different in this form of weight loss than roasts evaluated immediately following freezing (Table 184).



Table 174. General table illustrating the percent thaw loss for beef roasts throughout storage and according to final storage temperature and rate of freezing - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing					
Immediately following freezing, 1 day					
6 months	-10T	-6.19 + 1.98	-7.71 + 3.03	-7.74 + 2.93	-8.02 + 1.11
	0T	8.64 + 1.47	10.27 + 2.40	10.12 + 2.58	8.44 + 2.39
	20T	10.44 + 1.17	7.97 + 4.94	10.88 + 2.97	9.90 + 1.58
9 months	-10T	11.67 + 1.90	10.32 + 1.79	10.93 + 1.96	12.08 + 2.32
	0T	9.26 + 1.90	8.51 + 3.44	11.59 + 2.05	9.08 + 2.40
	20T	8.33 + 1.21	8.20 + 2.51	11.47 + 1.75	12.13 + .48
12 months	-10T	12.75 + 2.40	8.84 + 1.75	15.10 + 2.82	15.69 + 2.15
	0T	11.03 + 2.84	7.63 + 1.61	10.37 + 1.66	12.93 + 2.17
	20T	10.20 + 1.40	9.99 + 2.95	11.94 + 2.71	12.05 + 2.89
20N	20T	12.70 + 1.62	11.18 + 2.30	12.43 + 3.62	14.82 + 1.23
	20N	9.30 + 1.83	8.96 + 2.64	13.05 + 2.03	11.74 + 2.76

<sup>a</sup> Mean + S.D. T = temperature abused, N = not temperature abused.



Table 175. Effect of freezing rate on percent thaw loss for beef roasts following nine or twelve months storage

Evaluation time, months	Freezing Rate, hours to 0°F			
	24	48	72	96
9	10.11 $\pm$ .64bc	8.52 $\pm$ .64c	12.72 $\pm$ .64a	12.30 $\pm$ .64ab
12	11.31 $\pm$ .69ab	9.60 $\pm$ .77b	11.58 $\pm$ .69ab	13.27 $\pm$ .77a

abc Means on the same line with different letters are different ( $P < .05$ ).  
Mean  $\pm$  S.E.



Table 176. Effect of final storage temperature on percent thaw loss for beef roasts following nine and twelve months storage

Evaluation time, months	Final Storage Temperature, °F		
	-10	0	+20
9	9.61 $\pm$ .55b	10.03 $\pm$ .55b	13.1 $\pm$ .55a
12	10.49 $\pm$ .60b	11.05 $\pm$ .70ab	12.78 $\pm$ .60a

ab Means on the same line with different letters are different ( $P < .05$ ). Mean  $\pm$  S.E.





Table 177. General table illustrating the percent change in weight of beef roasts from before freezing until after thawing throughout storage and according to final storage temperature and rate of freezing - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Immediately following freezing, 1 day		-6.19 + 1.98	- 7.71 + 3.03	- 7.74 + 2.93	- 8.02 + 1.11
6 months	-10T	- 8.65 + 1.48	-10.37 + 2.4	-10.13 + 2.59	- 8.41 + 2.41
	0T	-10.48 + 1.26	- 8.01 + 4.92	-10.92 + 2.96	- 9.92 + 1.65
	20T	-11.75 + 1.92	-10.44 + 1.89	-11.09 + 2.06	-12.13 + 2.31
9 months	-10T	- 9.20 + 1.87	- 8.50 + 3.45	-11.54 + 2.04	- 9.03 + 2.38
	0T	- 8.30 + 1.23	- 8.22 + 2.50	-11.40 + 1.78	-12.02 + .55
	20T	-12.86 + 2.4	- 9.03 + 1.72	-15.13 + 2.80	-15.76 + 2.11
12 months	-10T	-11.14 + 2.78	- 7.59 + 1.65	-10.51 + 1.58	-12.90 + 2.20
	0T	-10.28 + 1.43	-10.49 + 2.39	-12.06 + 2.65	-12.48 + 2.52
	20T	-12.92 + 1.6	-11.39 + 2.36	-12.60 + 3.65	-14.95 + 1.28
	20N	- 9.53 + 1.94	- 9.17 + 1.94	-13.20 + 1.97	-11.84 + 2.87

<sup>a</sup> Mean ± S.D. T = temperature abused, N = not temperature abused.



Table 178. Effect of final storage temperature on percent change in weight from before freezing until after thawing for beef roasts following nine and twelve months storage

Evaluation time, months	Final Storage Temperature, °F		
	-10	0	+20
9	-9.61 $\pm$ .57b	-10.01 $\pm$ .62b	-13.22 $\pm$ .57a
12	-10.53 $\pm$ .56b	-11.37 $\pm$ .56ab	-13.00 $\pm$ .56a

ab Means on the same line with different letters are different ( $P < .05$ ). Mean  $\pm$  S.E.



Table 179. Effect of freezing rate on percent change in weight from just before freezing until after thawing for beef roasts following nine months storage

Freezing Rate, hours to 0°F			
24	48	72	96
-10.14 $\pm$ .66ab	-8.61 $\pm$ .66b	-12.74 $\pm$ .66a	-12.29 $\pm$ .74a

ab Means on the same line with different letters are different ( $P < .05$ ).  
Mean  $\pm$  S.E.



Table 180. Effect of various storage time comparisons on percent change in weight from just before freezing until after thawing for beef roasts

<u>Evaluation time</u>	
<u>Immediately after freezing, 1 day</u>	<u>6 months</u>
-7.41a	-10.19b
<u>Immediately after freezing, 1 day</u>	<u>9 months</u>
-7.41a	-10.92b

ab Difference between means on the same line significant ( $P < .05$ ).

Mean





Table 181. Effect of storage time (immediately following freezing, twelve months) on percent change in weight of beef roasts from just before freezing until after thawing<sup>a</sup>

<u>Evaluation Time</u>	
Immediately following freezing, 1 day	12 months <sup>c</sup>
-6.12b	-11.95a
Immediately following freezing, 1 day	12 months <sup>d</sup>
-7.41b	-11.61a

ab Means on the same line with different letters are different ( $P < .05$ ). Mean  $\pm$  S.E.

<sup>c</sup>Includes only +20°F final temperature stored product.

<sup>d</sup>Includes only temperature abused product.



Table 182. Effect of storage time (immediately following freezing, nine months) on percent change in weight of beef roasts from just before freezing until after thawing<sup>a</sup>

9 months				
Immediately after freezing, 1 day	Initial storage temperature, °F =	-10	0	
	Final storage temperature, °F =	-10	-10	+20
-7.41	-7.99	-8.24	-11.81	-11.15 -11.73 -14.58

<sup>a</sup>Data for roasts obtained immediately following freezing had to be recalculated and thus no statistical analysis possible. Mean.







Table 184. Effect of storage time (immediately following freezing, 12 months) on percent change in weight of beef roasts from just before freezing until after thawing

12 Months Storage				
Immediately after freezing, 1 day	Initial storage temperature, °F =	-10		0
	Temperature abuse =	T	N	T N
-7.63c		-11.74ab	-11.47b	-14.90a -9.68bc

abc Means on the same line with different letters are different ( $P < .05$ ). Mean.  
Includes just +20°F final storage temperature product.





The general table providing information about weight loss from just after freezing until after thawing is shown in Table 185. Again, increases in storage time and the use of +20°F final storage temperature produced the greatest losses. Twelve months storage, however, was the only time interval to produce more loss than that noted just after freezing (Table 186). Further breakdown of the twelve-month values (Table 187) revealed that -10°F and 0°F final storage temperatures from roasts initially stored at -12°F were not different than values recorded immediately following freezing.

The following series of tables depicts percent cooking loss. Advances in storage time seemed to reduce cooking loss (Table 188). This is not too surprising since thaw losses seemed to be greater in roasts stored longer and essentially what would be lost in thawing would not be available for a loss during cooking. Following nine months storage, an interaction involving initial and final storage temperature and rate of freezing was found (Table 189), but only one specific treatment difference was detected. Following twelve months of storage, +20°F final storage temperature produced more cooking loss than -10°F (Table 190). Six, nine and twelve months storage produced less cooking loss than that found immediately following freezing (Table 191, 192). There are some indications following six months, that the losses were more extensive if 0°F rather than -10°F was used as the initial storage temperature (Table 193). Such was also the case following nine months storage, but only if roasts were frozen to 0°F in 24 hr (Table 194).



Table 185. General table illustrating the percent change in weight of beef roasts from just after freezing until after thawing throughout storage and according to final storage temperature and rate freezing - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24'	48	72	96
Before freezing					
Immediately following freezing, 1 day					
6 months	-10T	-6.22 + 1.98	- 7.7 + 2.99	- 7.86 + 2.91	- 8.03 + 1.10
	0T	- 8.65 + 1.47	-10.41 + 2.38	-10.19 + 2.64	- 8.45 + 2.39
	20T	-10.51 + 1.25	- 8.03 + 4.94	-10.96 + 3.00	- 9.96 + 1.67
9 months	-10T	-11.77 + 1.91	-10.45 + 1.88	-11.13 + 2.07	-12.16 + 2.32
	0T	- 9.23 + 1.87	- 8.54 + 3.49	-11.58 + 2.05	- 9.08 + 2.41
	20T	- 8.31 + 1.25	- 8.25 + 2.51	-11.48 + 1.66	-11.99 + .27
12 months	-10T	-12.88 + 2.44	- 9.06 + 1.70	-15.16 + 2.76	-15.79 + 2.09
	0T	-11.17 + 2.81	- 7.60 + 1.63	-10.42 + 1.66	-12.93 + 2.23
	20T	-10.32 + 1.41	-10.51 + 2.36	-12.12 + 2.68	-12.52 + 2.54
20N	20T	-12.95 + 1.60	-11.42 + 2.35	-12.65 + 3.68	-14.99 + 1.26
	20N	- 9.55 + 1.91	- 9.17 + 2.69	-13.24 + 1.92	-11.86 + 2.86

a Mean ± S.D. T = temperature abused, N = not temperature abused.

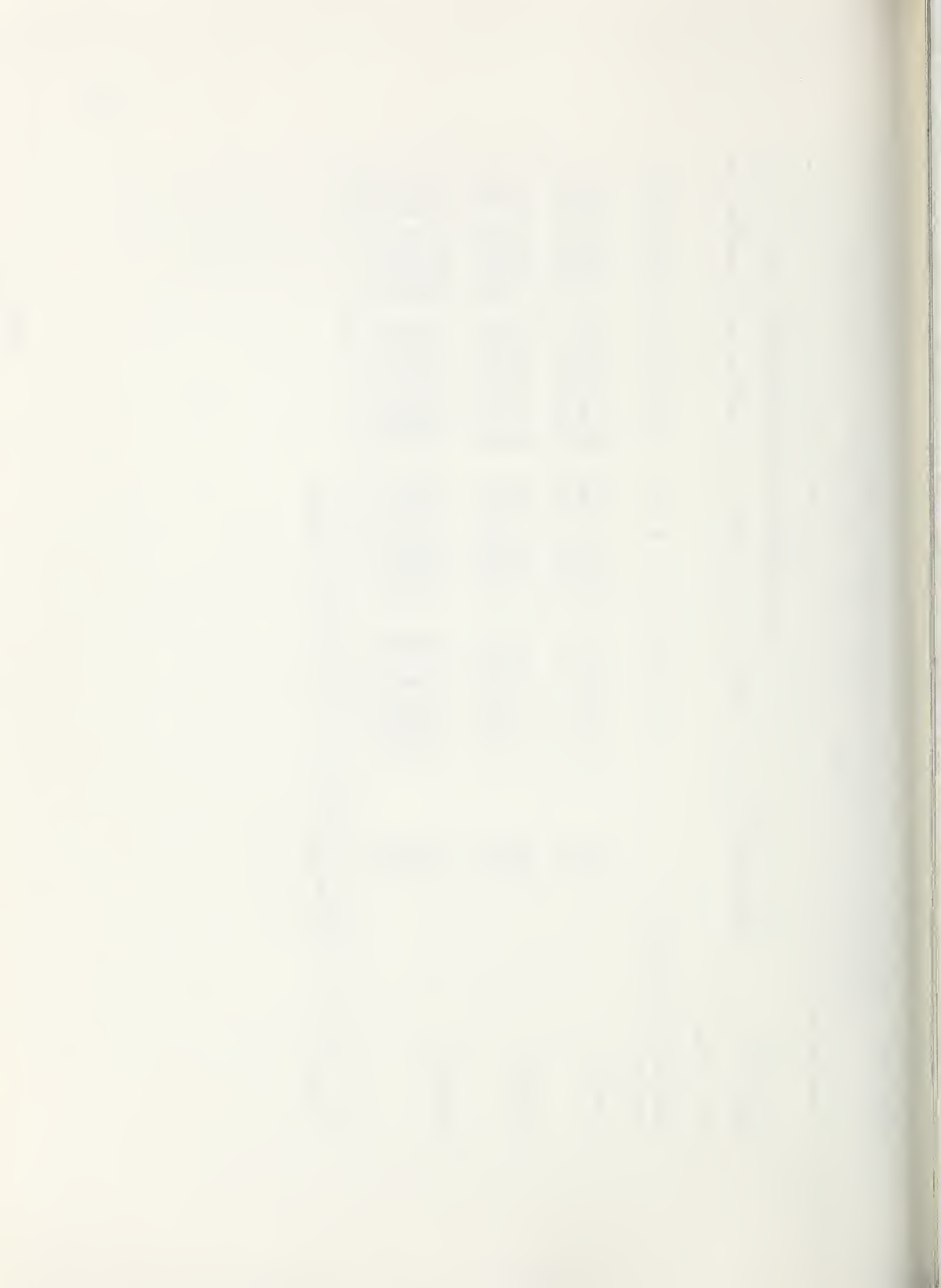


Table 186. Effect of storage time (immediately following freezing, twelve months) on percent change in weight of beef roasts from just after freezing until after thawing

<u>Evaluation Time</u>	
Immediately following freezing, 1 day	12 months <sup>c</sup>
-7.45b	-11.63a
Immediately following freezing, 1 day	12 months <sup>d</sup>
-7.66b	-11.98a

ab Differences between means significant ( $P < .05$ ).  
Mean.

<sup>c</sup>Includes only temperature abused product.

<sup>d</sup>Includes only +20°F final storage temperature product.



Table 187. Effect of storage time (immediately following freezing, 12 months) on percent change in weight of beef roasts from just after freezing until after thawing

		12 months	
Immediately after freezing, 1 day	Initial storage temperature, °F =	-10	0
	Final storage temperature, °F =	-10	0
-7.45c		-8.77bc	-10.23bc
		-11.44ab	-12.29ab
			-12.51ab
			-14.57a

abc Means on the same line with different letters are different ( $P < .05$ ). Mean.  
Includes just temperature abused product.





Table 188. General table illustrating the percent cooking loss for beef roasts throughout storage and according to final storage temperature and rate of freezing - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		25.48 ± 2.08	23.04 ± 2.44	24.27 ± 5.20	26.82 ± 3.23
Immediately following freezing, 1 day		26.49 ± .65	24.75 ± 3.40	24.74 ± 1.24	27.08 ± 1.69
6 months	-10T	22.00 ± 3.65	24.82 ± 3.39	23.65 ± 2.96	20.41 ± .78
	0T	24.10 ± 1.10	21.71 ± 3.14	22.06 ± .78	19.83 ± 3.11
	20T	23.25 ± 1.26	23.08 ± 5.74	21.74 ± .96	21.41 ± 1.92
9 months	-10T	20.53 ± 2.97	22.65 ± .97	20.94 ± 2.88	21.3 ± 1.53
	0T	22.09 ± 3.87	21.27 ± 2.91	19.71 ± 2.26	21.48 ± 1.11
	20T	23.02 ± .87	22.63 ± 2.04	22.32 ± .80	19.86 ± 1.81
12 months	-10T	21.63 ± .94	19.45 ± 2.49	21.51 ± .81	18.93 ± 2.18
	0T	20.69 ± 1.97	20.09 ± 3.22	22.37 ± 2.74	18.99 ± 1.64
	20T	23.99 ± 2.57	22.85 ± 1.26	22.46 ± 2.76	19.23 ± 1.04
	20N	23.86 ± 2.06	20.10 ± 2.51	19.86 ± 2.93	22.37 ± 3.07

<sup>a</sup>Mean ± S.D. T = temperature abused, N = not temperature abused.



Table 189. Interaction effect of initial storage temperature, final storage temperature and rate of freezing on percent cooking loss for beef roasts following nine months storage

Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
-10	-10	21.89 + 1.19ab	22.39 + 1.19ab	18.81 + 1.19ab	20.83 + 1.19ab
	0	25.37 + 1.19a	19.29 + 1.19ab	21.36 + 1.19ab	20.82 + 1.19ab
	20	22.49 + 1.19ab	22.25 + 1.19ab	22.62 + 1.19ab	19.42 + 1.19ab
0	-10	19.17 + 1.19ab	22.90 + 1.19ab	23.07 + 1.19ab	21.77 + 1.19ab
	0	18.8 + 1.19ab	23.25 + 1.19ab	18.06 + 1.19b	22.15 + 1.19ab
	20	23.54 + 1.19ab	23.01 + 1.19ab	22.01 + 1.19ab	20.31 + 1.19ab

ab Any mean comparison with the same letters is not different ( $P > .05$ ). Mean ± S.E.



Table 190. Effect of final storage temperature on percent cooking loss for beef roasts following twelve months storage

Final Storage Temperature, °F		
-10	0	+20
20.38 $\pm$ .48b	20.54 $\pm$ .48ab	22.13 $\pm$ .48a

ab Means on the same line with different letters are different ( $P < .05$ ). Mean  $\pm$  S.E.



Table 191. Effect of storage time (immediately following freezing, either six or nine months) on percent cooking loss for cooked beef roasts

<u>Evaluation Time</u>	
Immediately following freezing, 1 day	6 months
25.77a	22.34b
Immediately following freezing, 1 day	9 months
25.77a	21.48b

ab Differences between means on same line significant ( $P < .05$ ). Means.





Table 192. Effect of storage time (immediately following freezing, twelve months) on percent cooking loss of beef roasts

<u>Evaluation Time</u>	
Immediately following freezing, 1 day	12 months <sup>c</sup>
25.76a	21.84b

Immediately following freezing, 1 day	12 months <sup>d</sup>
25.53a	21.02b

ab Means on the same line with different letters are different ( $P < .05$ ). Mean + S.E.

<sup>c</sup>Includes only +20°F final temperature stored product.

<sup>d</sup>Includes only temperature abused product.



Table 193. Effect of storage time (immediately following freezing, six months) on percent cooking loss for cooked beef roasts<sup>a</sup>

		6 months			
Immediately after freezing, 1 day	Initial storage temperature, °F =	-10		0	
	Final storage temperature, °F =	-10	0	+20	+20
25.77		24.65	23.90	23.13	20.79
					19.96
					21.60

<sup>a</sup>Due to data recalculation, no statistical analysis possible. Means.



Table 194. Interaction effect of storage time (immediately following freezing, nine months), initial storage temperature, final storage temperature and rate of freezing on percent cooking loss for cooked beef roasts<sup>a</sup>

Evaluation time	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F			
			24	48	72	96
Immediately following freezing, 1 day			26.49	23.36	24.75	27.43
9 months	-10	-10	24.26	22.22	19.76	20.85
		0	27.74	19.12	22.31	20.84
		+20	24.86	22.07	23.57	19.44
	0	-10	16.81	23.08	22.13	21.75
		0	16.43	23.43	17.12	22.13
		+20	21.17	23.19	21.07	20.29

<sup>a</sup>Data recalculation necessary - no statistical analyses available. Means.



Following twelve months of storage, cooking losses were higher for roasts frozen to 0°F in 72 hr vs roasts frozen to 0°F in 96 hr. No differences in cooking loss were found between these rates after nine months storage (Table 195). After twelve months storage, roasts initially stored at -10°F did not differ in cooking loss compared to those calculated right after freezing (Table 196). Roasts stored at 0°F initially had lower cooking losses at twelve months.

The amount of the cooking loss that was represented as drip loss is given in the next series of tables. In contrast to evaporative losses, much less of the drip loss is composed of moisture. Since weight losses previously described (mostly moisture), increased with longer storage, it could be assumed that drip loss as a component of cooking loss would increase with advancements in storage time and the use of +20°F final storage temperature. There is a slight evidence of this in the general table (Table 197).

Following twelve months of storage, roasts frozen to 0°F in 48 hr had more drip loss when initially and finally stored at 0°F compared to roasts frozen to 0°F in 96 hr under these conditions (Table 198). Other rate x storage temperature interactions were nonsignificant ( $P > .05$ ) for drip loss at this storage time. This is some indication that temperature abused roasts had less drip loss following twelve months storage, but only for 0°F in 24 and 96 hr rates (Table 199). Increases in storage time did slightly increase drip loss in some comparisons (Tables 200, 201). Inconsistent differences in drip loss between initial storage temperatures of 0°F and -10°F were apparent between storage times of nine and twelve months and the various freezing rates (Table 202).





Table 195. Interaction effect of storage time (nine, twelve months) and freezing rate on percent cooking loss for cooked beef roasts

Evaluation time, months	Freezing Rate, hours to 0°F			
	24	48	72	96
9	21.88 $\pm$ .55a	22.18 $\pm$ .55a	20.99 $\pm$ .55ab	20.88 $\pm$ .55ab
12	22.10 $\pm$ .55a	20.80 $\pm$ .55ab	22.12 $\pm$ .55a	19.05 $\pm$ .55b

ab Any mean comparison with the same letters is not different ( $P > .05$ ).  
Mean  $\pm$  S.E.



Table 196. Effect of storage time (immediately following freezing, 12 months) on percent cooking loss for beef roasts

		12 Months Storage			
Immediately after freezing, 1 day	Initial storage temperature, °F = Temperature abuse =	-10		0	
		T	N	T	N
25.96a		23.46ab	22.56ab	20.64b	20.70b

ab Means on the same line with different letters are different ( $P < .05$ ). Mean.  
Includes just +20°F final storage temperature product.



Table 197. General table illustrating the percent drip loss for cooked beef roasts throughout storage and according to final storage temperature and freezing rate - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F				
		24	48	72	96	
Before freezing		1.52 ±	1.77 ±	1.72 ±	1.78 ±	.53
Immediately following freezing, 1 day		2.23 ±	2.10 ±	1.65 ±	2.02 ±	.28
6 months	-10T	2.33 ±	2.36 ±	1.56 ±	2.17 ±	.90
	0T	2.03 ±	1.96 ±	1.48 ±	1.25 ±	.38
	20T	1.79 ±	2.32 ±	1.92 ±	1.65 ±	.33
9 months	-10T	2.25 ±	2.84 ±	1.79 ±	1.89 ±	.73
	0T	2.58 ±	1.96 ±	1.57 ±	1.62 ±	.21
	20T	2.41 ±	2.20 ±	2.43 ±	1.86 ±	.36
12 months	-10T	1.82 ±	1.86 ±	2.27 ±	1.66 ±	.63
	0T	1.89 ±	2.44 ±	2.18 ±	1.49 ±	.58
	20T	2.34 ±	2.53 ±	2.61 ±	2.11 ±	.71
	20N	3.44 ±	2.33 ±	2.07 ±	2.45 ±	.35

<sup>a</sup>Mean ± S.D. T = temperature abused, N = not temperature abused.



Table 198. Interaction effect of initial storage temperature, final storage temperature and rate of freezing on percent drip loss during cooking for beef roasts following twelve months storage

Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
-10	-10	2.18 + .35ab	1.80 + .35ab	2.15 + .35ab	2.15 + .35ab
	0	1.89 + .35ab	1.62 + .35ab	1.60 + .35ab	1.93 + .35ab
	20	3.10 + .35ab	2.12 + .35ab	2.79 + .35ab	1.61 + .35ab
0	-10	1.45 + .35ab	1.92 + .35ab	2.39 + .35ab	1.17 + .35ab
	0	1.88 + .35ab	3.25 + .35a	2.76 + .35ab	1.05 + .35b
	20	1.57 + .35ab	2.94 + .35ab	2.42 + .35ab	2.60 + .35ab

ab Any mean comparison with the same letters is not different ( $P > .05$ ); Mean + S.E.





Table 199. Interaction effect of temperature abuse and rate of freezing on percent drip loss during cooking for beef roasts following twelve months storage<sup>a</sup>

Temperature abuse	Freezing Rate, hours to 0°F			
	24	48	72	96
T	2.34 $\pm$ .28	2.53 $\pm$ .28	2.61 $\pm$ .28	2.11 $\pm$ .28
N	3.44 $\pm$ .28	2.33 $\pm$ .28	2.07 $\pm$ .28	2.45 $\pm$ .28

<sup>a</sup>Interaction significant ( $P < .05$ ) by analysis of variance, but not by HSD. Mean  $\pm$  S.E. T = temperature abused, N = not temperature abused.



Table 200. Effect of certain storage time comparisons on percent drip loss during cooking for cooked beef roasts

Evaluation Time	
Immediately before freezing	Immediately after freezing, 1 day
1.70b	2.00a
6 months	9 months
1.90 $\pm$ .07b	2.12 $\pm$ .07a

ab Means on the same line are different ( $P < .05$ ).  
Mean  $\pm$  S.E.



Table 201. Effect of storage time (immediately following freezing, twelve months) on percent drip loss during cooking of beef roasts

<u>Evaluation Time</u>	
Immediately following freezing, 1 day	12 months
2.00a	2.48b

ab Difference between means significant ( $P < .05$ ).  
Mean  $\pm$  S.E. Includes just  $+20^{\circ}\text{F}$  final storage  
temperature product.



Table 202. Interaction effect of storage time (nine, twelve months), initial storage temperature and freezing rate on percent drip loss during cooking for beef roasts<sup>a</sup>

Evaluation time, months	Initial storage temperature, °F	Freezing Rate, hours to 0°F			
		24	48	72	96
9	-10	2.48 + .23	2.40 + .23	1.93 + .23	1.54 + .23
	0	2.34 ± .23	2.26 ± .23	2.18 ± .23	2.04 ± .23
12	-10	2.39 + .23	1.85 + .23	1.92 + .23	1.90 + .23
	0	1.64 ± .23	2.70 ± .23	2.52 ± .23	1.61 ± .23

<sup>a</sup>Interaction effect significant by analysis of variance, but not by HSD. Mean ± S.E.





General information regarding evaporative losses is provided in Table 203. As expected in regards to storage time, evaporative losses decrease. An interaction involving initial and final storage temperature and rate of freezing at nine months storage is provided in Table 204. No consistent patterns in evaporative losses were noted, although roasts frozen to 0°F in 96 hr and stored at +20°F did have low evaporative losses.

After twelve months storage, roasts frozen to both 0°F in 24 and 72 hr had more evaporative loss than roasts frozen to 0°F in 96 hr (Table 205). Increases in storage time produced decreases in evaporative losses (Table 206, 207). Following six months storage, there are indications that initial storage at -10°F produced more evaporative losses than 0°F storage (Table 208). Much of the interaction depicted in Table 209 centers around the high evaporative losses for 0°F in 24 hr frozen roasts stored initially at -10°F and the low evaporative losses for roasts of this freezing rate stored initially at 0°F. Also, final temperature storage at 0°F produced considerable variability. At twelve months of storage, roasts stored initially at -10°F and finally at +20°F had no differences in evaporative losses in comparison to roasts samples right after freezing (Table 210).

The next several sections of tables (Tables 211-225) contain information concerning certain cooking properties that really shouldn't be affected in a logical fashion by the variables studied and thus are more of academic interest.

Table 226 illustrates the percent cooling loss values in a general context. Values tended to be highest (expected to some degree) in roasts sampled prior to freezing. Roasts frozen to 0°F in 24 and finally stored at -10°F had more cooling loss than roasts frozen to 0°F in 48 hr and finally stored at -10°F when evaluations occurred at six months. Also at



Table 203. General table illustrating the percent evaporative loss for cooked beef roasts throughout storage and according to final storage temperature and freezing rate - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		23.95 ± 2.01	21.27 ± 2.35	22.55 ± 5.35	25.03 ± 3.28
Immediately following freezing, 1 day		24.26 ± 3.75	22.65 ± 3.32	23.09 ± 1.23	25.06 ± 1.74
6 months	-10T	19.67 ± 3.73	22.45 ± 3.06	22.09 ± 2.67	18.24 ± 1.46
	0T	22.07 ± .97	19.75 ± 3.57	20.61 ± .72	18.58 ± 2.79
	20T	21.46 ± 1.27	20.76 ± 4.77	19.82 ± 1.49	19.76 ± 2.16
9 months	-10T	18.28 ± 3.22	19.80 ± 1.64	19.15 ± 2.84	19.41 ± 1.03
	0T	19.50 ± 3.27	19.31 ± 2.91	18.14 ± 1.91	19.86 ± .98
	20T	20.61 ± 1.05	20.43 ± 1.52	19.89 ± .79	18.0 ± 1.62
12 months	-10T	19.82 ± 1.19	17.59 ± 2.30	19.24 ± .34	17.27 ± 1.58
	0T	18.81 ± 2.07	17.65 ± 2.43	20.20 ± 2.59	17.5 ± 1.35
	20T	21.65 ± 1.71	20.33 ± .71	19.85 ± 3.06	17.12 ± .94
	20N	20.42 ± 2.86	17.77 ± 2.12	17.79 ± 2.54	19.92 ± 3.27

<sup>a</sup>Mean ± S.D. T = temperature abused, N = not temperature abused.



Table 204. Interaction effect of initial storage temperature, final storage temperature and rate of freezing on percent evaporative loss during cooking for beef roasts following nine months storage<sup>a</sup>

Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
-10	-10	19.93 + 1.21	19.37 + 1.21	17.00 + 1.21	19.4 + 1.21
	0	22.28 + 1.21	17.28 + 1.21	19.47 + 1.21	19.27 + 1.21
	20	20.1 + 1.21	20.06 + 1.21	20.53 + 1.21	17.78 + 1.21
0	-10	16.64 + 1.21	20.23 + 1.21	21.30 + 1.21	19.42 + 1.21
	0	16.73 + 1.21	21.34 + 1.21	16.82 + 1.21	20.46 + 1.21
	20	21.12 + 1.21	20.8 + 1.21	19.25 + 1.21	18.23 + 1.21

<sup>a</sup>Interaction effect significant (P<.05) by analysis of variance, but not by HSD. Mean + S.E.



Table 205. Effect of freezing rate on percent evaporative loss during cooking for cooked beef roasts following twelve months of storage

Freezing Rate, hours to 0°F			
24	48	72	96
20.09 $\pm$ .51a	18.52 $\pm$ .51ab	19.76 $\pm$ .51a	17.30 $\pm$ .51b

ab Means on the same line with different letters are different ( $P < .05$ ).  
Mean  $\pm$  S.E.





Table 206. Effect of various storage time comparisons on percent evaporative loss in cooking loss for cooked beef roasts

Evaluation Time	
Immediately following freezing, 1 day	6 months
24.26a	20.44
Immediately following freezing, 1 day	9 months
24.26a	19.37
6 months	9 months
20.44 $\pm$ .36b	19.37 $\pm$ .36c

.a Due to recalculation, statistical analyses could not be made.

bc Differences significant ( $P < .05$ ). Mean  $\pm$  S.E.



Table 207. Effect of storage time (immediately following freezing, twelve months) on percent evaporative loss during cooking of beef roasts

Evaluation Time	
Immediately following freezing, 1 day	12 months <sup>ab</sup>
23.43	18.93

Immediately following freezing, 1 day	12 months <sup>ac</sup>
23.79	19.36

<sup>a</sup>Due to data recalculations, no statistical analyses possible.

<sup>b</sup>Includes just temperature abused product.

<sup>c</sup>Includes just +20°F final storage temperature product.



Table 208. Effects of storage time (immediately following freezing, six months) on percent evaporative losses during cooking for cooked beef roasts<sup>a</sup>

6 months					
Immediately after freezing, 1 day	Initial storage temperature, °F =		0		
	Final storage temperature, °F =		-10	+20	+20
23.76	22.36	22.16	21.11	18.86	18.34 19.79

<sup>a</sup>Due to data recalculation, statistical analysis not possible. Means.

[illegible]

Table 209. Interaction effect of storage time (immediately following freezing, nine months), initial storage temperature, final storage temperature and rate of freezing on percent evaporative loss during cooking for cooked beef roasts<sup>a</sup>

Evaluation time	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F			
			24	48	72	96
Immediately following freezing, 1 day						
			24.26	21.07	23.09	25.27
9 months	-10	-10	22.59	19.06	17.94	19.32
		0	24.94	16.97	20.41	19.19
		+20	22.76	19.75	21.46	17.70
	0	-10	13.98	20.55	20.36	19.50
		0	14.07	21.65	15.88	20.54
		+20	18.46	21.11	18.31	18.31

<sup>a</sup>Due to data reanalysis, statistical analysis not possible. Means.





Table 210. Effect of storage time (immediately following freezing, 12 months) on percent evaporative loss during cooking for beef roasts<sup>a</sup>

		12 months			
Initial storage temperature, °F =		-10		0	
Immediately after freezing, 1 day	Final storage temperature, °F =	-10		0	
		-10	+20	-10	+20
24.26a		19.80bc	19.34bc	21.15ab	17.16c
					17.73bc
					18.32bc

abc Means on the same line with different letters are different ( $P < .05$ ). Mean.  
Includes just temperature abused product.



Table 211. General table illustrating the highest internal temperature during cooking for cooked beef roasts throughout storage and according to final storage temperature and freezing rate - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		73.25 ± 1.28	73.19 ± 2.64		73.00 ± 1.63
Immediately following freezing, 1 day		74.5 ± 1.91	73.67 ± .82	74.37 ± 1.51	72.75 ± 1.28
6 months	-10T	70.12 ± .85	70.25 ± .96	70.25 ± .65	69.87 ± 1.44
	0T	70.50 ± 1.29	71.00 ± 1.96	70.75 ± 1.19	69.12 ± .63
	20T	70.25 ± 1.50	70.62 ± 2.29	69.75 ± 1.32	70.37 ± 1.18
9 months	-10T	69.75 ± .50	70.00 ± 1.41	69.37 ± .85	70.75 ± .96
	0T	70.37 ± 2.06	70.50 ± 3.11	69.62 ± .63	70.50 ± 1.29
	20T	70.87 ± 1.44	70.12 ± 1.31	70.50 ± 1.22	69.37 ± .50
12 months	-10T	70.00 ± .58	70.37 ± 1.49	69.50 ± 1.29	69.62 ± 1.97
	0T	70.37 ± 1.11	70.87 ± 1.93	70.50 ± 1.58	69.25 ± 1.26
	20T	69.37 ± 1.49	70.75 ± 1.26	70.00 ± 2.12	70.25 ± 2.21
	20N	69.75 ± .29	69.25 ± .50	69.75 ± 1.50	69.25 ± .65

<sup>a</sup>Mean ± S.D. T = temperature abused, N = not temperature abused.



Table 212. Effect of initial storage temperature on highest internal temperature obtained following cooking of beef roasts after twelve months storage

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<u>Initial storage temperature, °F</u>	
<u>-10</u>	<u>0</u>
70.79 $\pm$ .35a	69.35 $\pm$ .33b

---

ab Difference between means significant ( $P < .05$ ). Mean  $\pm$  S.E.



Table 213. Effect of various storage time comparisons on highest internal temperature obtained in beef roasts following cooking

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<u>Evaluation time</u>	
<u>Immediately following freezing, 1 day</u>	<u>6 months</u>
74.30 $\pm$ .37a	70.24 $\pm$ .37b
<u>Immediately following freezing, 1 day</u>	<u>9 months</u>
74.30 $\pm$ .47a	70.12 $\pm$ .47b

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ab Means on the same line bearing different letters are different ( $P < .05$ ).  
Mean  $\pm$  S.E.





Table 214. Effect of storage time (immediately following freezing, twelve months) on highest internal temperature obtained following cooking of beef roasts

Evaluation Time	
Immediately following freezing, 1 day	12 months <sup>c</sup>
74.30 $\pm$ .48a	70.07 $\pm$ .48b
Immediately following freezing, 1 day	12 months <sup>d</sup>
73.80 $\pm$ .44a	69.79 $\pm$ .44b

ab Means on the same line with different letters are different ( $P < .05$ ).

<sup>c</sup>Includes just temperature abused product.

<sup>d</sup>Includes just +20°F final storage temperature product.



Table 215. Interaction effect of storage time (nine, twelve months) and initial storage temperature on highest internal temperature obtained following cooking of beef roasts

Evaluation time, months	Initial storage temperature, °F	
	-10	0
9	69.94 $\pm$ .32ab	70.58 $\pm$ .35ab
12	70.79 $\pm$ .35a	69.35 $\pm$ .32b

ab Any mean comparisons with the same letters are not different ( $P > .05$ ).  
Mean  $\pm$  S.E.



Table 216. General table illustrating the time (min) to reach highest cooked temperature for beef roasts following removal from ovens throughout storage and according to final storage temperature and rate of freezing - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		16.97 ± 5.74	9.19 ± 5.20		12.5 ± 5.82
Immediately following freezing, 1 day		18.50 ± 6.06	12.92 ± 2.08	15.27 ± 2.92	8.94 ± 2.97
6 months	-10T	7.00 ± 2.12	8.00 ± 2.86	11.00 ± 1.41	5.75 ± 4.65
	0T	12.00 ± 3.54	6.62 ± 4.52	11.37 ± 4.96	4.00 ± 3.16
	20T	7.50 ± 0.00	6.12 ± 2.78	8.12 ± 6.49	9.25 ± 3.75
9 months	-10T	7.87 ± 2.84	11.25 ± 4.52	9.12 ± 6.92	10.00 ± 2.74
	0T	8.50 ± 7.00	9.12 ± 7.51	7.50 ± 3.85	13.00 ± 1.00
	20T	7.87 ± 2.01	8.87 ± 4.75	10.62 ± 6.18	6.37 ± 1.53
12 months	-10T	11.75 ± 5.07	9.37 ± 4.46	9.37 ± 6.00	9.37 ± 1.89
	0T	8.00 ± 4.71	8.5 ± 6.47	9.75 ± .96	9.12 ± 5.63
	20T	11.87 ± 2.78	18.5 ± 1.35	10.37 ± 6.29	4.87 ± 5.54
	20N	6.87 ± 5.54	4.5 ± 2.16	5.62 ± 4.61	7.37 ± 4.59

<sup>a</sup>Mean ± S.D. T = temperature abused, N = not temperature abused.



Table 217. Effect of freezing rate on time (min) required for cooked beef roasts to reach highest internal temperature following cooking at various intervals

Evaluation time	Freezing rate, hours to 0°F			
	24	48	72	96
Just before freezing <sup>d</sup>	16.97 ± 2.09	9.19 ± 1.95		12.5 ± 2.76
Immediately following freezing, 1 day	18.50 ± 1.85a	12.92 ± 1.31bc	15.27 ± 1.14ab	8.94 ± 1.14c

abc Means on the same line with different letters are different (P<.05).

d Differences significant (P<.05) by Analysis of Variance, but not by HSD.





Table 218. Interaction effect of temperature abuse and rate of freezing on time (min) following cooking for cooked beef roasts to reach their highest temperature, following twelve months storage

Temperature abuse	Freezing Rate, hours to 0°F			
	24	48	72	96
T	11.87 $\pm$ 2.07ab	18.5 $\pm$ 2.07a	10.37 $\pm$ 2.07ab	4.87 $\pm$ 2.07b
N	6.87 $\pm$ 2.07b	4.5 $\pm$ 2.07b	5.62 $\pm$ 2.07b	7.37 $\pm$ 2.07b

ab Any mean comparison with different letters is different ( $P < .05$ ).  
Mean  $\pm$  S.E. T = temperature abused, N = not temperature abused.



Table 219. Effect of initial storage temperature on time (min) required for cooked beef roasts to reach their highest internal temperature following cooking after twelve months storage

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<u>Initial storage temperature, °F</u>	
<u>-10</u>	<u>0</u>
10.34 $\pm$ 1.04a	7.16 $\pm$ 1.04b

---

ab Difference between means significant ( $P < .05$ ). Mean  $\pm$  S.E.



Table 220. Effect of various storage time comparisons on time (min) required for cooked beef roasts to reach their highest internal temperature following cooking

<u>Evaluation time</u>	
<u>Immediately following freezing, 1 day</u>	<u>6 months</u>
15.07 $\pm$ 1.11a	8.06 $\pm$ 1.12b
<u>Immediately following freezing, 1 day</u>	<u>9 months</u>
15.07 $\pm$ 1.11a	9.07 $\pm$ 1.11b

ab Means on the same line bearing different superscripts were different ( $P < .05$ ). Mean  $\pm$  S.E.

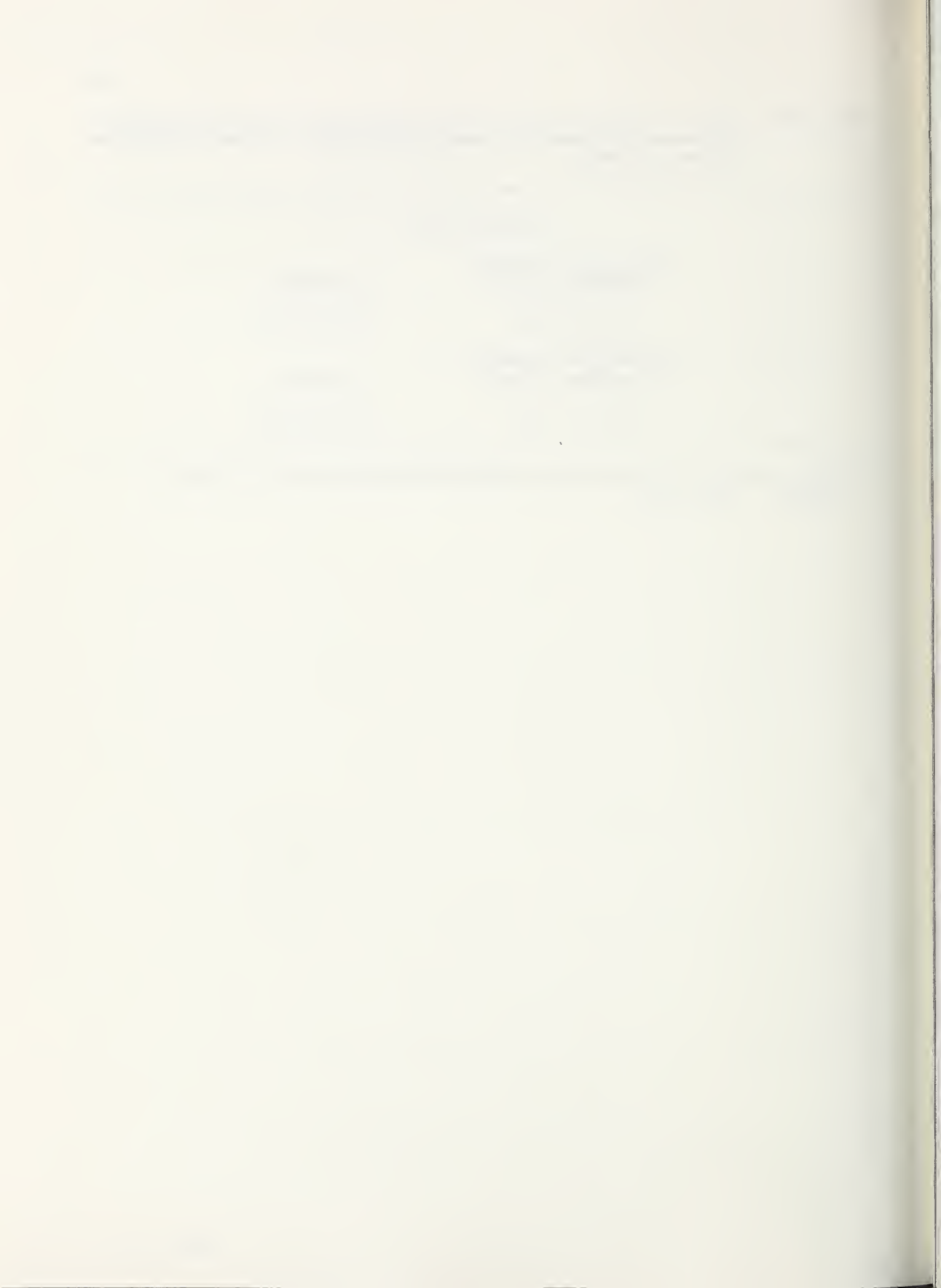


Table 221. Effect of storage time (immediately following freezing, twelve months) on time (min) required for beef roasts to reach their highest temperature following cooking

Evaluation Time	
Immediately following freezing, 1 day	12 months <sup>c</sup>
15.01 $\pm$ 1.42a	10.07 $\pm$ 1.42b
Immediately following freezing, 1 day	12 months <sup>d</sup>
13.91 $\pm$ 1.04a	8.75 $\pm$ 1.04b

ab Means on the same line with different letters are different ( $P < .05$ ). Mean  $\pm$  S.E.

<sup>c</sup>Includes just temperature abused product.

<sup>d</sup>Includes just +20°F final storage temperature product.





Table 222. Effect of storage time (immediately following freezing, six months) on time (min) for cooked beef roasts to reach highest internal temperature following cooking

		Evaluation time			
		6 months			
Immediately following freezing, 1 day	Initial storage temperature, °F =	-10		0	
	Final storage Temperature, °F =	0	+20	-10	+20
15.09 + .96a		9.00 + 1.31b	7.06 + 1.31b	7.19 + 1.31b	6.87 + 1.31b 9.94 + 1.31ab 8.31 + 1.31b

ab Means on the same line with the same letters are not different ( $P>.05$ ). Mean + S.E.



Table 223. Interaction effect of storage time (just after freezing, nine months), initial storage temperature, final storage temperature and rate of freezing on time (min) to reach highest cooked temperature for cooked beef roasts

Evaluation time	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to °F			
			24	48	72	96
Immediately following freezing, 1 day			22.0 ± 2.71a	13.58 ± 2.29ab	15.2 ± 1.77ab	9.5 ± 1.77ab
9 months	-10	-10	8.92 ± 3.69ab	13.42 ± 3.4ab	3.55 ± 3.07b	6.25 ± 3.07b
		0	14.42 ± 3.69ab	3.17 ± 3.4b	10.05 ± 3.07ab	10.75 ± 3.07ab
		+20	6.67 ± 3.69b	9.17 ± 3.4ab	8.05 ± 3.07ab	5.25 ± 3.07b
	0	-10	6.83 ± 3.69b	9.08 ± 3.4ab	14.7 ± 3.07ab	13.75 ± 3.07ab
		0	2.58 ± 3.69b	15.08 ± 3.4ab	4.95 ± 3.07b	15.25 ± 3.07ab
		+20	9.08 ± 3.69ab	8.58 ± 3.4ab	13.2 ± 3.07ab	7.5 ± 4.22ab

ab Any mean comparison with the same letter is not different ( $P > .05$ ). Mean ± S.E.



Table 224. Interaction effect of storage time (six, nine months), initial storage temperature final storage temperature and freezing rate on the time (min) to reach highest cooked temperature following removal from ovens for cooked beef roasts<sup>a</sup>

Evaluation time, months	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to °F			
			24	48	72	96
6	-10	-10	6.00 + 4.2	6.00 + 2.4	12.00 + 2.4	9.50 + 2.4
9		-10	8.50 + 2.4	13.25 + 2.4	3.25 + 2.4	8.00 + 2.4
6		0	7.50 + 4.2	7.00 + 2.4	8.75 + 2.4	3.00 + 2.4
9		0	14.00 + 2.4	3.00 + 2.4	9.75 + 2.4	12.50 + 2.4
6	0	+20	6.75 + 4.2	4.00 + 2.4	11.00 + 2.4	6.25 + 2.4
9		+20	6.25 + 2.4	9.00 + 2.4	7.75 + 2.4	7.00 + 2.4
6		-10	3.25 + 4.2	10.00 + 2.4	10.00 + 2.4	2.00 + 2.4
9		-10	7.25 + 2.4	9.25 + 2.4	15.00 + 2.4	12.00 + 2.4
6	0	0	11.50 + 4.2	6.25 + 2.4	14.00 + 2.4	5.00 + 2.4
9		0	3.00 + 2.4	15.25 + 2.4	5.25 + 2.4	13.50 + 2.4
6		+20	7.00 + 4.2	8.25 + 2.4	5.25 + 2.4	12.25 + 2.4
9		+20	9.50 + 2.4	8.75 + 2.4	13.50 + 2.4	3.25 + 2.4

<sup>a</sup>Interaction significant ( $P < .05$ ) by analysis of variance, but is too large to test by HSD. Mean + S.E.

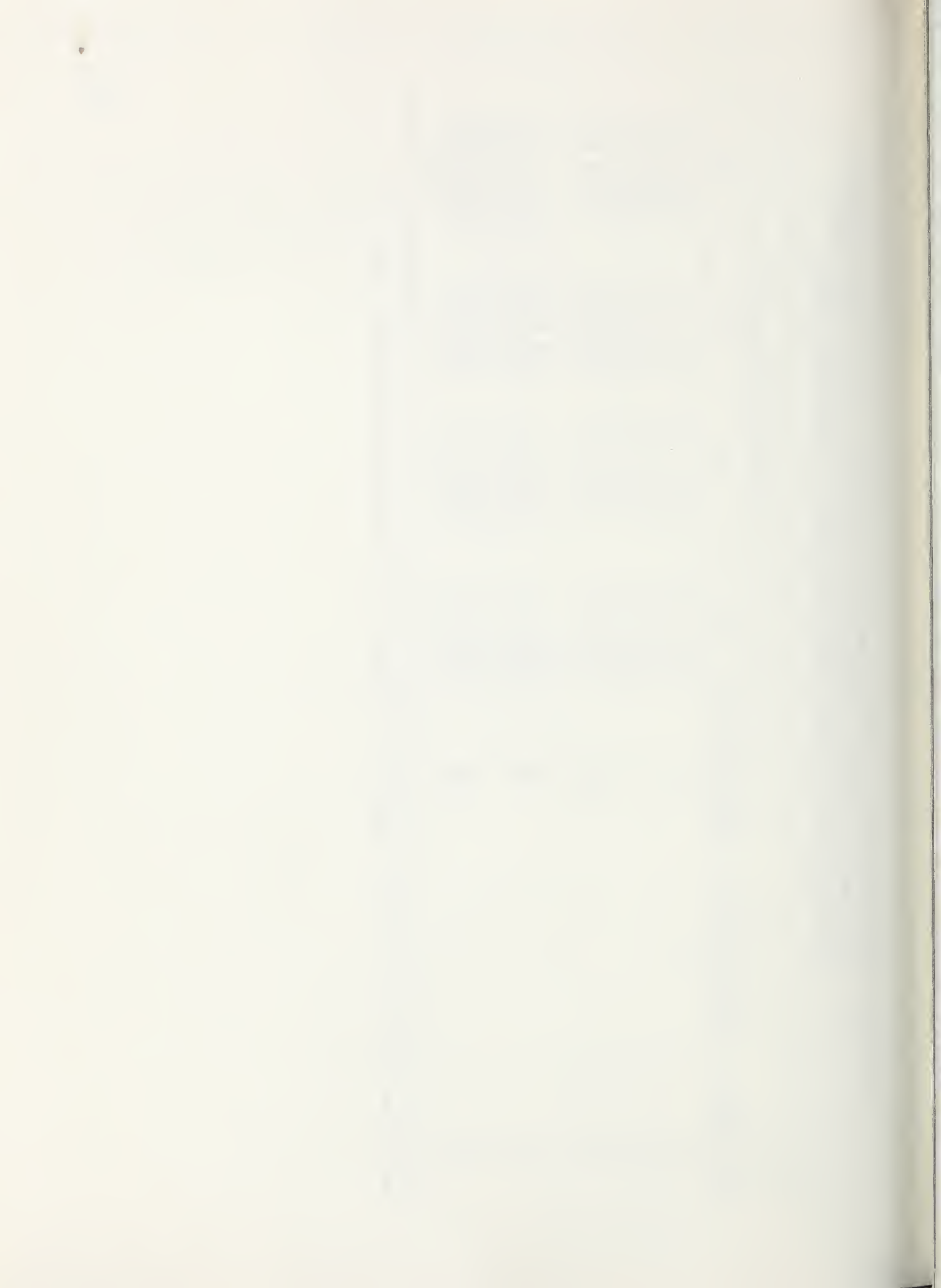


Table 225. Effect of storage time (immediately following freezing, 12 months) on time (min) required for beef roasts to reach their highest temperature following cooking

		12 Months Storage			
Initial storage temperature, °F =		-10		0	
Immediately after freezing, 1 day	Temperature abuse	T	N	T	N
13.91 ± .79a		13.75 ± 1.29a	6.94 ± 1.29b	9.06 ± 1.29ab	5.25 ± 1.29b

ab Means on the same line with different letters are different ( $P < .05$ ). Mean ± S.E.  
Includes just +20°F final storage temperature product.





Table 226. General table illustrating the percent cooling loss for cooked roasts throughout storage and according to final storage temperature and rate of freezing - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		5.29 + .62	5.82 + .29	6.37 + 3.43	4.67 + .94
Immediately following freezing, 1 day		5.06 + .67	4.61 + .52	5.13 + .44	4.81 + .31
6 months	-10T	5.40 + .45	4.27 + .43	4.87 + .48	4.61 + .32
	0T	5.24 + .42	5.21 + 1.33	5.36 + .83	4.22 + .25
	20T	4.74 + .32	4.31 + .77	4.66 + 1.00	5.25 + 1.13
9 months	-10T	5.36 + .60	4.86 + .90	4.94 + .25	4.86 + .27
	0T	5.23 + .16	4.92 + 1.18	5.34 + .32	4.92 + .61
	20T	5.31 + .46	5.17 + .58	5.58 + .56	4.86 + .81
12 months	-10T	5.17 + .62	5.02 + .80	5.31 + .31	5.26 + .80
	0T	5.34 + .36	5.85 + .83	4.87 + .60	5.39 + .75
	20T	4.55 + .33	5.46 + .96	5.48 + .38	4.98 + .45
	20N	4.58 + .25	4.25 + .18	4.51 + 1.13	4.10 + 1.1

<sup>a</sup>Mean + S.D. T = temperature abused, N = not temperature abused.



this time roasts frozen to 0°F in 72 hr and finally stored at 0°F and roasts frozen to 0°F in 96 hr and finally stored at +20°F had more cooling loss than roasts frozen to 0°F in 96 hr and finally stored at 0°F (Table 227). For roasts stored initially at -10°F, the use of 0°F and +20°F final storage temperatures reduced cooling losses, while the opposite was true for roasts initially stored at 0°F (Table 228) following six months of storage. After twelve months of storage, the use of -10°F initial storage temperature produced more cooling loss for roasts frozen to 0°F in 24 and 96 hr, compared to the 0°F initial storage temperature. The opposite was the case (although to a lesser degree) for the 0°F in 48 and 72 hr freezing rates (Table 229).

More cooling loss was found for roasts stored nine months than six months (Table 230). There was some indication that the use of +20°F reduced the cooling loss for 0°F in 24 and 48 hr frozen roasts after six months, but not at nine months (Table 231). Storage for twelve months produced an increase in cooling loss if just temperature abused product was evaluated; for +20°F stored product, twelve months storage reduced cooling losses (Table 232). However, across all treatments at twelve months, temperature abuse did increase cooling losses (Table 233). In comparing specific initial and final storage temperature combinations at twelve months, only the use of -10°F initially and finally produced a change (increase) over the cooling losses found for cooked roasts right after freezing (Table 234). None of the temperature abuse-initial storage temperature combinations were significantly ( $P < .05$ ) different in cooling loss from roasts measured right after freezing (Table 235). There was some indication that twelve months storage produced more cooling loss than nine months storage for roasts initially stored at -10°F, while these storage



Table 227. Interaction effect of final storage temperature and rate of freezing on percent cooling loss in cooked beef roasts following six months storage

Final storage temperature, °F	Freezing rate, hours °F			
	24	48	72	96
-10	5.40 $\pm$ .18a	4.27 $\pm$ .25cd	4.87 $\pm$ .18abcd	4.61 $\pm$ .18abcd
0	5.24 $\pm$ .18abc	5.21 $\pm$ .18abc	5.36 $\pm$ .18a	4.22 $\pm$ .18d
+20	4.74 $\pm$ .18abcd	4.31 $\pm$ .25bcd	4.66 $\pm$ .18abcd	5.26 $\pm$ .18ab

abcd Any mean comparison with different letters is different ( $P < .05$ ) Mean  $\pm$  S.E.

The first part of the paper is devoted to a general discussion of the problem. It is shown that the problem is of great importance in the theory of differential equations. The second part is devoted to the construction of the solution. It is shown that the solution can be obtained by the method of variation of parameters. The third part is devoted to the study of the properties of the solution. It is shown that the solution is unique and stable. The fourth part is devoted to the application of the results to the theory of differential equations. It is shown that the results can be applied to the study of the stability of the equilibrium position of a mechanical system.

Table 228. Interaction effect of final storage temperature and initial storage temperature on percent cooling loss for cooked beef roasts following six months storage

Final storage temperature, °F	Initial storage temperature, °F	
	-10	0
-10	5.03 $\pm$ .12ab	4.55 $\pm$ .15bc
0	4.74 $\pm$ .12abc	5.28 $\pm$ .12a
+20	4.22 $\pm$ .12c	5.27 $\pm$ .15a

abc Any mean comparison with different letters is different ( $P < .05$ )  
Mean  $\pm$  S.E.





Table 229. Interaction effect of initial storage temperature and rate of freezing on percent cooling loss for cooked beef roasts following twelve months storage<sup>a</sup>

Initial storage temperature, °F	Freezing Rate, hours to 0°F			
	24	48	72	96
-10	5.32 $\pm$ .23	5.20 $\pm$ .23	5.18 $\pm$ .28	5.68 $\pm$ .23
0	4.72 $\pm$ .23	5.68 $\pm$ .23	5.26 $\pm$ .23	4.74 $\pm$ .23

<sup>a</sup>Interaction significant ( $P < .05$ ) by analysis of variance but not by HSD.  
Mean  $\pm$  S.E.



Table 230. Effect of storage time (six, nine months) on percent cooling loss for cooked beef roasts

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<u>Evaluation time, months</u>	
<u>6</u>	<u>9</u>
4.83 $\pm$ .12b	5.24 $\pm$ .12a

---

ab Difference between roasts significant ( $P < .05$ ). Mean  $\pm$  S.E.

Table

Eva  
time

a

t

Table 231. Interaction effect of storage time (six, nine months), final storage temperature and freezing rate on percent cooling losses for cooked beef roasts<sup>a</sup>

Evaluation time, months	Final storage temperature, °F	Freezing Rate, hours to 0°F		
		24	48	96
6	-10	5.40 + .25	5.03 + .36	4.61 + .25
	0	5.24 + .25	5.21 + .25	4.22 + .25
	20	4.74 + .25	3.93 + .36	5.62 + .25
9	-10	5.36 + .25	4.86 + .25	4.86 + .25
	0	5.23 + .25	4.92 + .25	4.92 + .25
	20	5.31 + .25	5.17 + .25	4.86 + .25

<sup>a</sup>Interaction significant ( $P < .05$ ) by analysis of variance, but not by HSD.  
Mean + S.E.

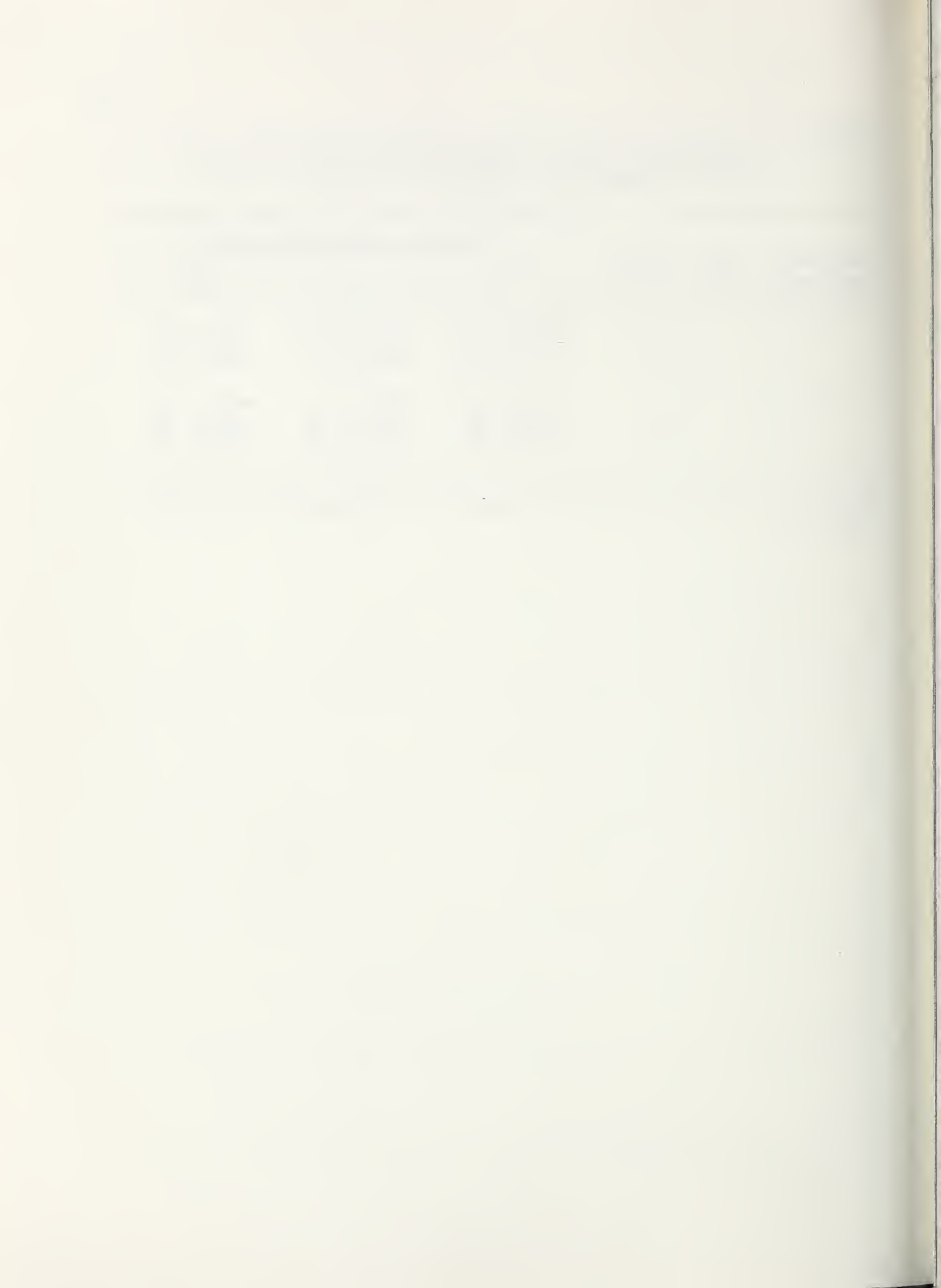


Table 232. Effect of storage time (immediately following freezing, twelve months) on percent cooling loss following cooking of beef roasts

Evaluation Time	
Immediately after freezing, 1 day	12 months <sup>c</sup>
4.88 $\pm$ .15b	5.22 $\pm$ .15a
Immediately after freezing, 1 day	12 months <sup>d</sup>
4.92 $\pm$ .08a	4.70 $\pm$ .08b

ab Means on the same line with different letters are different ( $P < .05$ ). Mean  $\pm$  S.E.

<sup>c</sup>Includes just temperature abused product.

<sup>d</sup>Includes just +20°F final temperature stored product.





Table 233. Effect of temperature abuse on percent cooling loss for cooked beef roasts following twelve months storage

<u>Temperature abuse</u>	
<u>T</u>	<u>N</u>
5.09 $\pm$ .18a	4.36 $\pm$ .16b

ab Difference between means significant ( $P < .05$ ). Mean  $\pm$  S.E.

T = temperature abused, N = not temperature abused. Includes only +20°F final storage temperature.



Table 234. Effect of storage time (immediately following freezing, 12 months) on percent cooling loss following cooking of beef roasts

		12 months			
Immediately after freezing, 1 day	Initial storage temperature, °F =	-10			
	Final storage temperature, °F =	-10	0	+20	0
4.88 ± .13bc		5.76 ± .23a	5.48 ± .23ab	5.28 ± .25abc	4.62 ± .23c
					5.25 ± .23abc
					4.91 ± .23bc

abc Means on the same line with the same letters are not different ( $P > .05$ ). Mean ± S.E. Includes just temperature abused product.

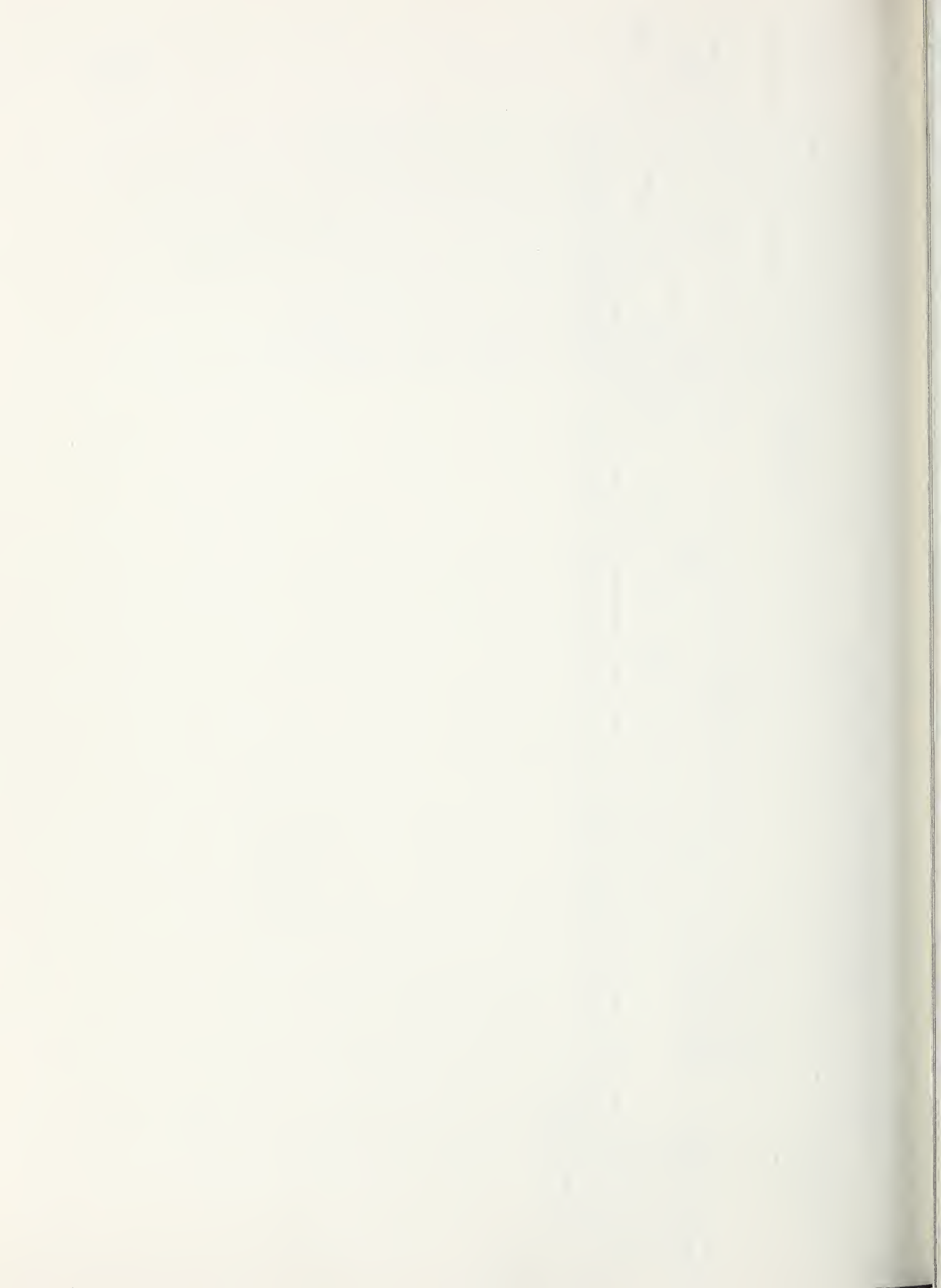
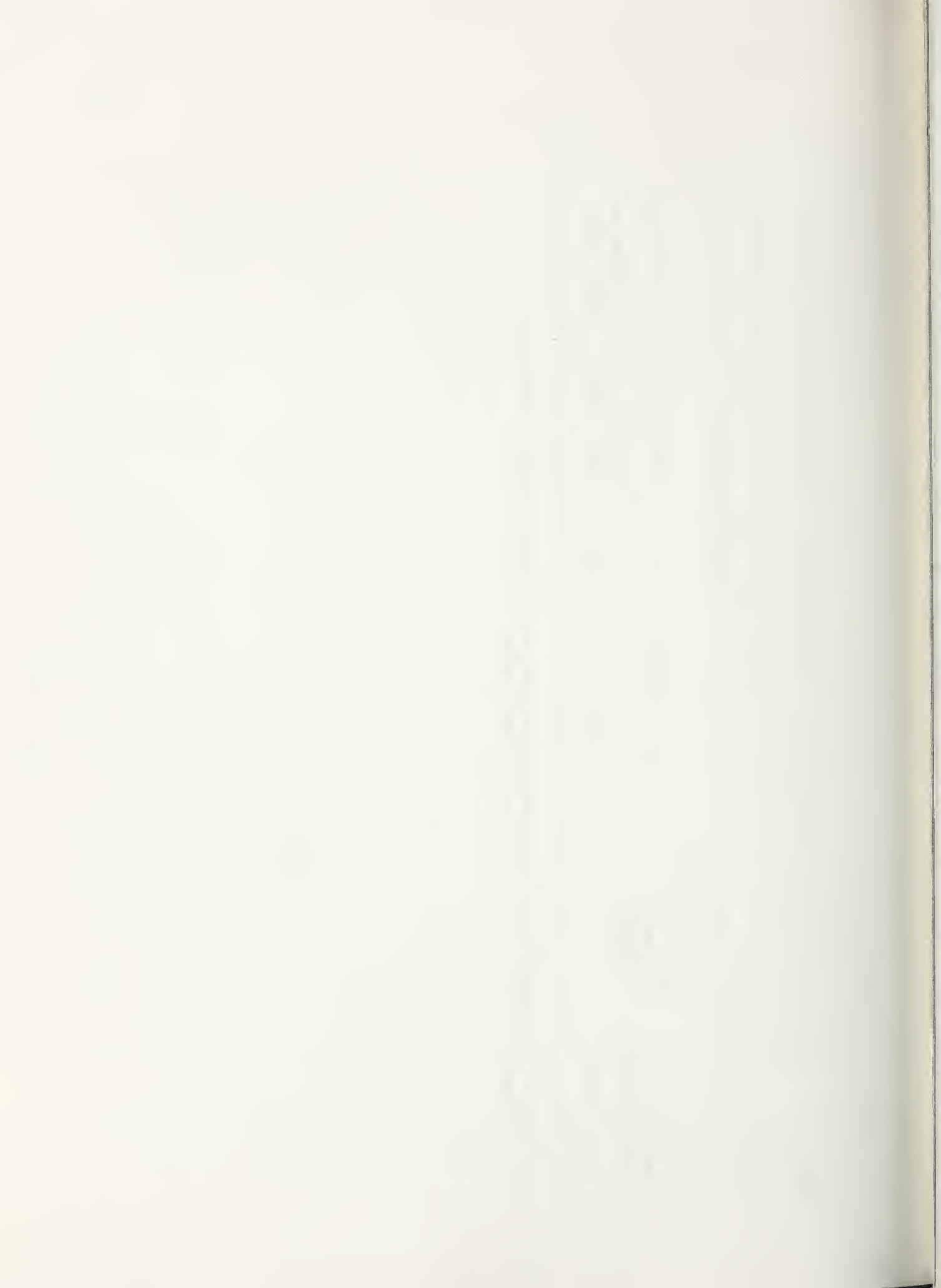


Table 235. Effect of storage time (immediately following freezing, 12 months) on percent cooling loss following cooking of beef roasts

		12 months storage			
		Initial storage temperature, °F =		0	
Immediately after freezing, 1 day	Temperature abuse	-10			
		T	N	T	N
4.92 ± .086abc		5.22 ± .24a	4.38 ± .23bc	4.95 ± .22ab	4.26 ± .22c

abc Means on the same line with the same letters are not different ( $P > .05$ ). Mean ± S.E.  
Includes just +20°F final temperature stored product.



time differences for 0°F initial storage temperature were not different (Table 236).

The following series of tables provide data on percent drip and evaporative losses and only select, interesting differences will be discussed. There were indications immediately before and after freezing and also following nine months storage that the 0°F in 96 hr rate had less drip loss during cooling than some of the faster freezing rates (Table 238). This rate effect at twelve months was somewhat initial storage temperature dependent with the lower drip loss for 0°F in 96 hr frozen roasts only apparent for roasts stored at 0°F initially (Table 241). Freezing in itself reduced the percent drip in cooling (Table 243).

As might be expected, the percent evaporative losses were higher for 0°F in 96 hr frozen roasts at certain times than the faster rates of freezing (Table 248). At six months of storage, -10°F initial storage temperature produced more evaporative loss during cooling for roasts ultimately stored at -10°F compared to the other two temperatures; the exact opposite was found for the 0°F initial storage temperature (Table 249). The -10°F initial temperature generated an increase in evaporative loss between six and nine months (Table 253). In comparing evaporative loss differences between roasts evaluated immediately following freezing vs those evaluated at twelve months, the same, but opposite situations to drip loss occurred (Table 256). For temperature abused roasts, twelve months storage produced an increase in evaporative loss, while for +20°F final storage temperature, twelve months storage resulted in a decrease in evaporative loss. At twelve months the 0°F in 96 hr freezing rate generated more evaporative loss than the 0°F in 24 hr freezing rate for roasts initially stored at -10°F (Table 259). Such freezing rate





Table 236. Interaction effect of storage time (nine, twelve months) and initial storage temperature on percent cooling loss following cooking of beef roasts<sup>a</sup>

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Evaluation time, months	<u>Initial storage temperature, °F</u>	
	-10	0
9	4.96 ± .12	5.14 ± .12
12	5.40 ± .12	5.05 ± .12

---

<sup>a</sup>Interaction effect significant by analysis of variance but not by HSD.  
Mean ± S.E does not include 0°F in 72 hr freezing rate product.



Table 237. General table illustrating the percent drip loss during cooling for cooked beef roasts throughout storage and according to final storage temperature and rate of freezing - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		1.64 ± .49	2.33 ± .62	1.45 ± .62	1.2 ± .67
Immediately following freezing, 1 day		1.35 ± .56	1.49 ± .33	1.54 ± .29	.60 ± .15
6 months	-10T	1.76 ± .17	.91 ± .22	1.38 ± .31	.94 ± .25
	0T	1.47 ± .47	2.19 ± .78	1.79 ± .67	.74 ± .34
	20T	1.28 ± .38	1.11 ± .27	1.27 ± .63	1.36 ± .62
9 months	-10T	1.85 ± .46	1.20 ± .48	1.38 ± .19	1.13 ± .094
	0T	1.65 ± .19	1.42 ± .47	1.84 ± .26	1.19 ± .18
	20T	1.78 ± .52	1.35 ± .45	2.06 ± .54	1.08 ± .54
12 months	-10T	2.05 ± .72	1.47 ± .23	1.24 ± .19	1.42 ± .63
	0T	1.87 ± .21	2.07 ± .75	.92 ± .24	1.42 ± .47
	20T	1.29 ± .36	1.63 ± .88	1.32 ± .57	1.31 ± .21
	20N	1.14 ± .23	.94 ± .43	1.06 ± .50	.67 ± .27

<sup>a</sup>Mean ± S.D. T = temperature abused, N = not temperature abused.



Table 238. Effect of freezing rate on percent drip loss during cooling for cooked beef roasts following various storage times

Evaluation time	Freezing rate, hours to 0°F			
	24	48	72	96
Just before freezing	1.64 $\pm$ .21ab	2.33 $\pm$ .30a	1.45 $\pm$ .21ab	1.20 $\pm$ .21b
Immediately following freezing, 1 day	1.35 $\pm$ .13a	1.49 $\pm$ .13a	1.54 $\pm$ .13a	0.60 $\pm$ .13b
9 months <sup>c</sup>	1.76 $\pm$ .13a	1.32 $\pm$ .13ab		1.13 $\pm$ .13b
9 months <sup>d</sup>	1.71 $\pm$ .15ab	1.38 $\pm$ .15ab	1.95 $\pm$ .18a	1.13 $\pm$ .15b

ab Means on the same line with different superscripts are different (P<.05). Mean  $\pm$  S.E.

c Does not include 0°F in 72 hr freezing rate.

d Includes only 0°F and +20°F final storage temperatures.



Table 239. Interaction effect of final storage temperature and rate of freezing on percent drip loss during cooling for cooked beef roasts following six months storage

Final storage temperature, °F	Freezing rate, hours °F			
	24	48	72	96
-10	1.76 $\pm$ .20ab	0.91 $\pm$ .28b	1.38 $\pm$ .20ab	.094 $\pm$ .20b
0	1.47 $\pm$ .20ab	2.19 $\pm$ .20a	1.79 $\pm$ .20ab	0.74 $\pm$ .20b
+20	1.28 $\pm$ .20ab	1.11 $\pm$ .28ab	1.27 $\pm$ .20ab	1.36 $\pm$ .20ab

ab Any mean comparison bearing the same letters is not different  
( $P > .05$ ) Mean  $\pm$  S.E.

TABLE I		TABLE II	
Summary of the results of the experiments		Summary of the results of the experiments	
Experiment	Results	Experiment	Results
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99	...	99	...
100	...	100	...



Table 240. Interaction effect of final storage temperature and initial storage temperature on percent drip loss during cooling for cooked beef roasts following six months storage<sup>a</sup>

Final storage temperature, °F	Initial storage temperature, °F	
	-10	0
-10	1.46 $\pm$ .14	1.04 $\pm$ .17
0	1.51 $\pm$ .14	1.58 $\pm$ .14
+20	0.96 $\pm$ .4	1.55 $\pm$ .17

a Interaction effect significant ( $P < .05$ ) by analysis of variance, but not by HSD. Mean  $\pm$  S.E.



Table 241. Interaction effect of initial storage temperature and rate of freezing on percent drip during cooling for cooked beef roasts following twelve months storage

Initial storage temperature, °F	Freezing Rate, hours to 0°F			
	24	48	72	96
-10	2.07 $\pm$ .15a	1.36 $\pm$ .15ab	1.08 $\pm$ .18b	1.68 $\pm$ .15ab
0	1.40 $\pm$ .15ab	2.09 $\pm$ .15a	1.24 $\pm$ .15b	1.08 $\pm$ .15b

ab Any mean comparison with different letters is different ( $P < .05$ ).  
Mean  $\pm$  S.E.



Table 242. Effect of temperature abuse on percent drip loss during cooling for cooked beef roasts following twelve months storage

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<u>Temperature abuse</u>	
<u>T</u>	<u>N</u>
1.37 $\pm$ .11a	.95 $\pm$ .10b

---

ab Difference between means significant ( $P < .05$ ). Mean  $\pm$  S.E.

T = temperature abused, N = not temperature abused. Includes only +20°F final storage temperature.



Table 243. Effect of storage time (just before and after freezing) on percent drip loss during cooling for cooked beef roasts

<u>Evaluation time</u>	
<u>Before freezing</u>	<u>Immediately following freezing, 1 day</u>
1.65 $\pm$ .11a	1.24 $\pm$ .09b

ab Difference between means significant ( $P < .05$ ). Mean  $\pm$  S.E.





Table 244. Interaction effect of storages time (nine, twelve months), initial storage temperature and freezing rate on percent drip loss days loss during cooling of cooked beef roasts

Evaluation time, months	Initial storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
9	-10	1.56 $\pm$ .21abc	1.27 $\pm$ .21c	1.84 $\pm$ .30abc	1.16 $\pm$ .21c
	0	1.87 $\pm$ .21abc	1.50 $\pm$ .21abc	2.30 $\pm$ .21ab	1.11 $\pm$ .21c
12	-10	1.79 $\pm$ .21abc	1.22 $\pm$ .21c	.90 $\pm$ .30c	1.62 $\pm$ .21abc
	0	1.37 $\pm$ .21bc	2.48 $\pm$ .21a	1.18 $\pm$ .21c	1.11 $\pm$ .21c

abc Any mean comparison with the same letters is not different ( $P > .05$ ). Mean  $\pm$  S.E.



Table 245. Interaction effect of storage time (nine, twelve months), initial storage temperature and freezing rate on percent drip loss during cooling for cooked beef roasts

Evaluation time, months	Initial storage temperature, °F	Freezing rate, hours to 0°F		
		24	48	96
9	-10	1.72 $\pm$ .17abc	1.21 $\pm$ .17abc	1.16 $\pm$ .17bc
	0	1.79 $\pm$ .17abc	1.44 $\pm$ .17abc	1.10 $\pm$ .17c
12	-10	2.07 $\pm$ .17ab	1.36 $\pm$ .17abc	1.68 $\pm$ .17abc
	0	1.40 $\pm$ .17abc	2.09 $\pm$ .17a	1.08 $\pm$ .17c

abc Any mean comparisons with different letters are not different ( $P < .05$ ).  
Mean  $\pm$  S.E.



Table 246. Interaction effect of storage time (nine, twelve months), initial storage temperature and final storage temperature on percent drip loss during cooling for beef roasts<sup>a</sup>

Evaluation time, months	Initial storage temperature, °F	Final Storage Temperature, °F		
		-10	0	+20
9	-10	2.06 + .20	2.14 + .20	2.08 + .20
	0	2.33 $\pm$ .20	1.73 $\pm$ .20	2.37 $\pm$ .20
12	-10	2.07 + .20	1.76 + .20	2.41 + .20
	0	1.73 $\pm$ .20	2.24 $\pm$ .20	2.38 $\pm$ .20

<sup>a</sup>Interaction effect significant ( $P < .05$ ) by analysis of variance, but not by HSD. Mean  $\pm$  S.E.



Table 247. General table illustrating the percent evaporative loss during cooling for cooked beef roasts throughout storage and according to final storage temperature and rate of freezing - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F				
		24	48	72	96	
Before freezing		3.66 ± .33	3.49 ± .34	4.97 ± 3.52	3.47 ± .36	
Immediately following freezing, 1 day		3.71 ± .33	3.11 ± .35	3.59 ± .24	4.21 ± .30	
6 months	-10T	3.64 ± .39	3.36 ± .54	3.49 ± .24	3.67 ± .068	
	0T	3.78 ± .10	3.02 ± .79	3.56 ± .19	3.48 ± .48	
	20T	3.46 ± .28	3.20 ± .68	3.39 ± .38	3.89 ± .58	
9 months	-10T	3.51 ± .20	3.65 ± .48	3.63 ± .06	3.73 ± .20	
	0T	3.57 ± .22	3.5 ± .78	3.50 ± .27	3.73 ± .44	
	20T	3.53 ± .12	3.82 ± .16	3.51 ± .26	3.78 ± .28	
12 months	-10T	3.12 ± .20	3.55 ± .62	4.07 ± .27	3.84 ± .22	
	0T	3.47 ± .28	3.78 ± .36	3.95 ± .43	3.96 ± .35	
	20T	3.26 ± .14	3.82 ± .14	4.16 ± .30	3.67 ± .29	
	20N	3.44 ± .18	3.31 ± .44	3.46 ± .63	3.43 ± .87	

<sup>a</sup>Mean ± S.D. T = temperature abused, N = not temperature abused.





Table 248. Effect of freezing rate on percent evaporative loss during cooling of cooked beef roasts following various storage periods

Evaluation time	Freezing rate, hours to 0°F			
	24	48	72	96
Immediately following freezing, 1 day	3.71 $\pm$ .11b	3.11 $\pm$ .11b	3.59 $\pm$ .11b	4.21 $\pm$ .12a
12 months	3.28 $\pm$ .086b	3.72 $\pm$ .086a	4.09 $\pm$ 0.86a	3.83 $\pm$ .086a

ab Means on the same line with different letters are different ( $P < .05$ ).  
 Mean  $\pm$  S.E.



Table 249. Interaction effect of final storage temperature and initial storage temperature on percent evaporative loss during cooling for cooked beef roasts following six months storage

Final storage temperature, °F	Initial storage temperature, °F	
	-10	0
-10	3.57 $\pm$ .09b	3.51 $\pm$ .11b
0	3.23 $\pm$ .09c	3.69 $\pm$ .09a
+20	3.26 $\pm$ .09c	3.71 $\pm$ .11a

abc Any mean comparison with different letters is different ( $P < .05$ )  
Mean  $\pm$  S.E.



Table 250. Interaction effect of initial storage temperature and rate of freezing on percent evaporative loss for cooked beef roasts during cooling following nine months storage<sup>a</sup>

Initial storage temperature, °F	Freezing rate, hours to °F		
	24	48	96
-10	3.67 $\pm$ .12	3.39 $\pm$ .12	3.73 $\pm$ .12
0	3.4 $\pm$ .12	3.93 $\pm$ .12	3.76 $\pm$ .12

<sup>a</sup>Interaction significant ( $P < .05$ ) by analysis of variance, but not by HSD. Mean  $\pm$  S.E.



Table 251. Interaction effect of storage time (six, nine months) and rate of freezing on percent evaporative loss during cooling for cooked beef roasts

Evaluation time, months	Freezing rate, hours to °F		
	24	48	96
6	3.62 $\pm$ .074a	3.27 $\pm$ .095b	3.68 $\pm$ .074a
9	3.54 $\pm$ .074ab	3.66 $\pm$ .074a	3.75 $\pm$ .074a

ab Any mean comparison with the same letter is not different ( $P > .05$ ). Mean  $\pm$  S.E.

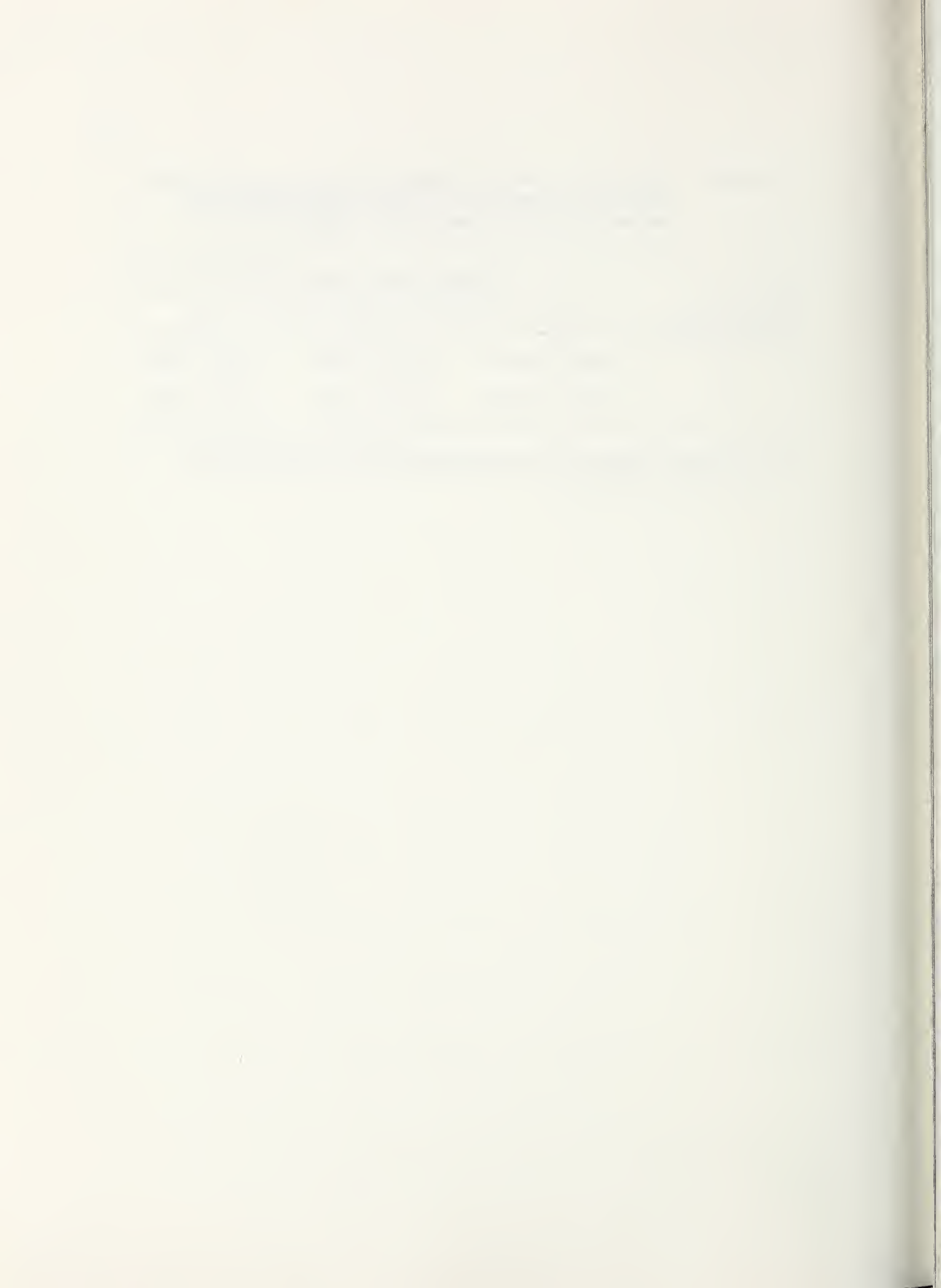




Table 252. Interaction effect of storage time (six, nine months) and initial storage temperature on percent evaporative loss during cooling for cooked beef roasts

Evaluation time, months	Initial Storage Temperature, °F	
	-10	0
6	3.32 $\pm$ .060b	3.73 $\pm$ .072a
9	3.60 $\pm$ .060a	3.70 $\pm$ .060a

ab Any mean comparison with the same letter is not different ( $P > .05$ ). Mean  $\pm$  S.E. Includes only 24, 48 and 96 hr freezing rates.

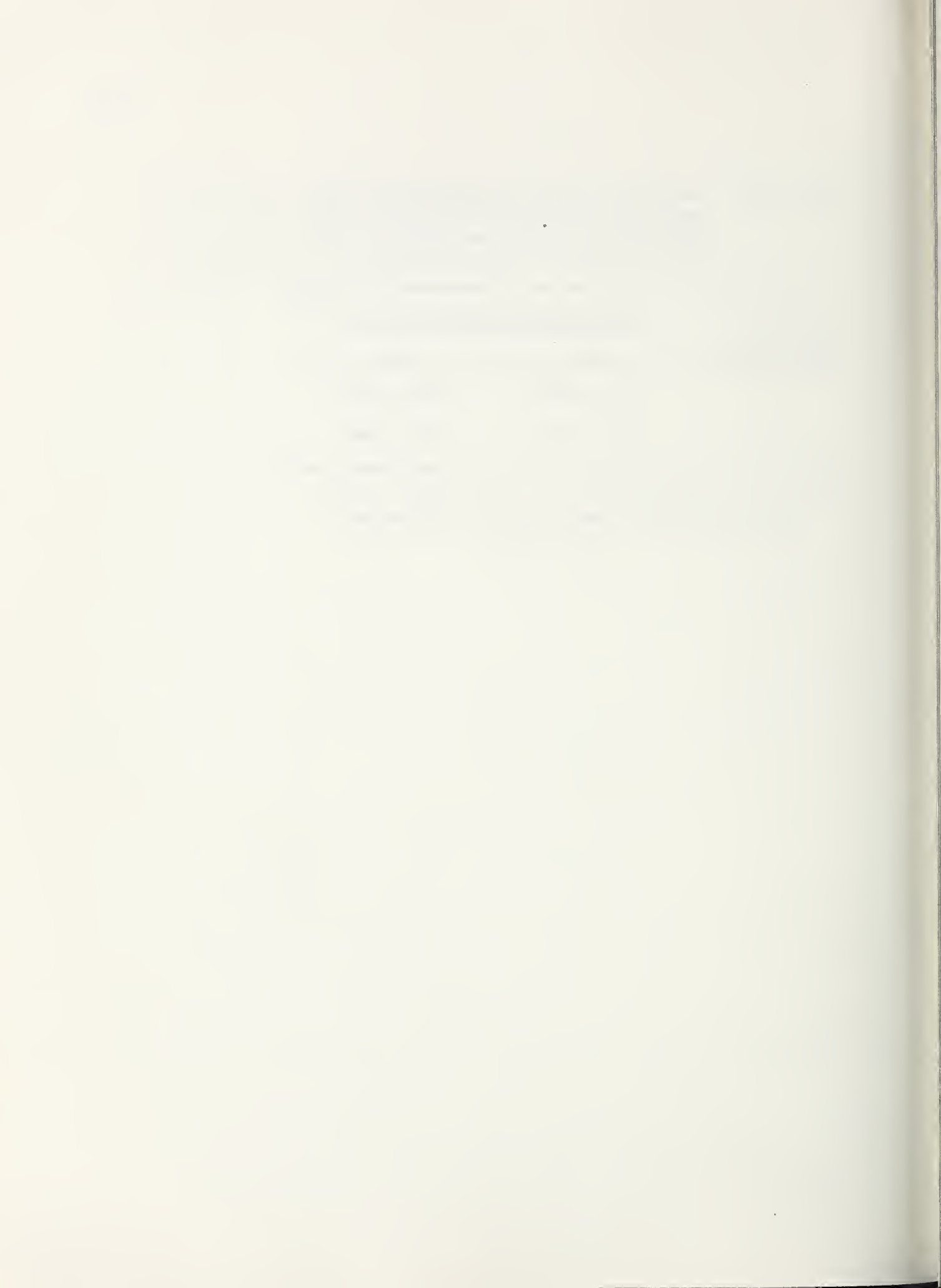


Table 253. Interaction effect of storage time (six, nine months) and initial storage temperature on percent evaporative loss during cooling of cooked beef roasts

Evaluation time, months	Initial storage temperature, °F	
	-10	0
6	3.24 $\pm$ .072b	3.70 $\pm$ .080a
9	3.58 $\pm$ .080a	3.68 $\pm$ .072a

ab Any mean comparison with the same letter is not different ( $P > .05$ ); Mean  $\pm$  S.E.  
Includes only 0 and +20°F final storage temperatures.



Table 254. Effect of storage time (immediately following freezing, nine months) on percent evaporative loss during cooling of cooked beef roasts

Evaluation time	
<u>Immediately after freezing, 1 day</u>	<u>9 months</u>
3.60 $\pm$ .10b	3.65 $\pm$ .10a

ab Difference between means significant ( $P < .05$ ). Mean  $\pm$  S.E.



Table 255. Interaction effect of storage time (immediately following freezing, nine months), initial storage temperature, final storage temperature and freezing rate on percent evaporative loss during cooling of cooked beef roasts<sup>a</sup>

Evaluation time	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F		
			24	48	96
Immediately after freezing, 1 day			3.69 $\pm$ .15	3.04 $\pm$ .15	4.06 $\pm$ .15
9 months	-10	-10	3.77 $\pm$ .26	4.19 $\pm$ .26	3.67 $\pm$ .26
		0	3.87 $\pm$ .26	3.14 $\pm$ .26	3.44 $\pm$ .26
		+20	3.72 $\pm$ .26	3.63 $\pm$ .26	3.80 $\pm$ .26
	0	-10	3.25 $\pm$ .26	3.67 $\pm$ .26	3.79 $\pm$ .26
		0	3.28 $\pm$ .26	3.85 $\pm$ .26	4.02 $\pm$ .26
		+20	3.34 $\pm$ .26	3.45 $\pm$ .26	3.76 $\pm$ .26

<sup>a</sup>Interaction effect significant ( $P < .05$ ) by analysis of variance, but not by HSD. Mean  $\pm$  S.E.





Table 256. Effect of storage time (immediately following freezing, twelve months) on percent evaporative loss during cooling of cooked beef roasts

<u>Evaluation Time</u>	
Immediately following freezing, 1 day	12 months <sup>c</sup>
3.59b $\pm$ .09b	3.72 $\pm$ .09a
Immediately following freezing, 1 day	12 months <sup>d</sup>
3.60 $\pm$ .09a	3.55 $\pm$ .09b

ab Means on the same line with different letters are different ( $P < .05$ ). Mean  $\pm$  S.E.

<sup>c</sup>Includes just temperature abused product.

<sup>d</sup>Includes just +20°F final storage temperature product.



Table 257. Interaction effect of storage time (immediately following freezing, twelve months), initial storage temperature, final storage temperature and freezing rate on percent evaporative loss during cooling of beef roasts following cooking

Evaluation time	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to U°F			
			24	48	72	96
Immediately following freezing, 1 day			3.68 + .15abc	3.04 + .15c	3.55 + .15abc	4.06 + .15abc
12 months	-10	-10	3.18 + .26bc	4.16 + .26abc	4.32 + .26ab	3.90 + .26abc
		0	3.55 + .26abc	4.09 + .26abc	3.79 + .26abc	4.10 + .26abc
		20	3.34 + .26abc	4.09 + .26abc	4.46 + .36a	3.71 + .26abc
	0	-10	3.06 + .26c	2.94 + .26c	3.82 + .26abc	3.78 + .26abc
		0	3.39 + .26abc	3.46 + .26abc	4.11 + .26abc	3.83 + .26abc
		20	3.17 + .26bc	3.56 + .26abc	3.80 + .26abc	3.64 + .26abc

abc Any mean comparisons with the same letters are not different ( $P < .05$ ). Mean + S.E. Includes just temperature abused product.



Table 258. Interaction effect of storage time (immediately following freezing, twelve months), initial storage temperature, temperature abuse and freezing rate on percent evaporative loss during cooling of cooked beef roasts

Evaluation time	Initial storage temperature, °F	Temperature abuse	Freezing rate, hours to 0°F			
			24	48	72	96
Immediately following freezing, 1 day			3.71 ± .13ab	3.11 ± .13ab	3.59 ± .13ab	4.25 ± .16a
12 months	-10	N	3.31 ± .34ab	2.95 ± .34ab	3.71 ± .34ab	3.72 ± .43ab
		T	3.36 ± .34ab	4.16 ± .34ab	4.36 ± .49a	3.90 ± .35ab
	0	N	3.52 ± .34ab	3.53 ± .34ab	3.13 ± .34ab	2.77 ± .35b
		T	3.20 ± .34ab	3.63 ± .34ab	3.83 ± .34ab	3.82 ± .35ab

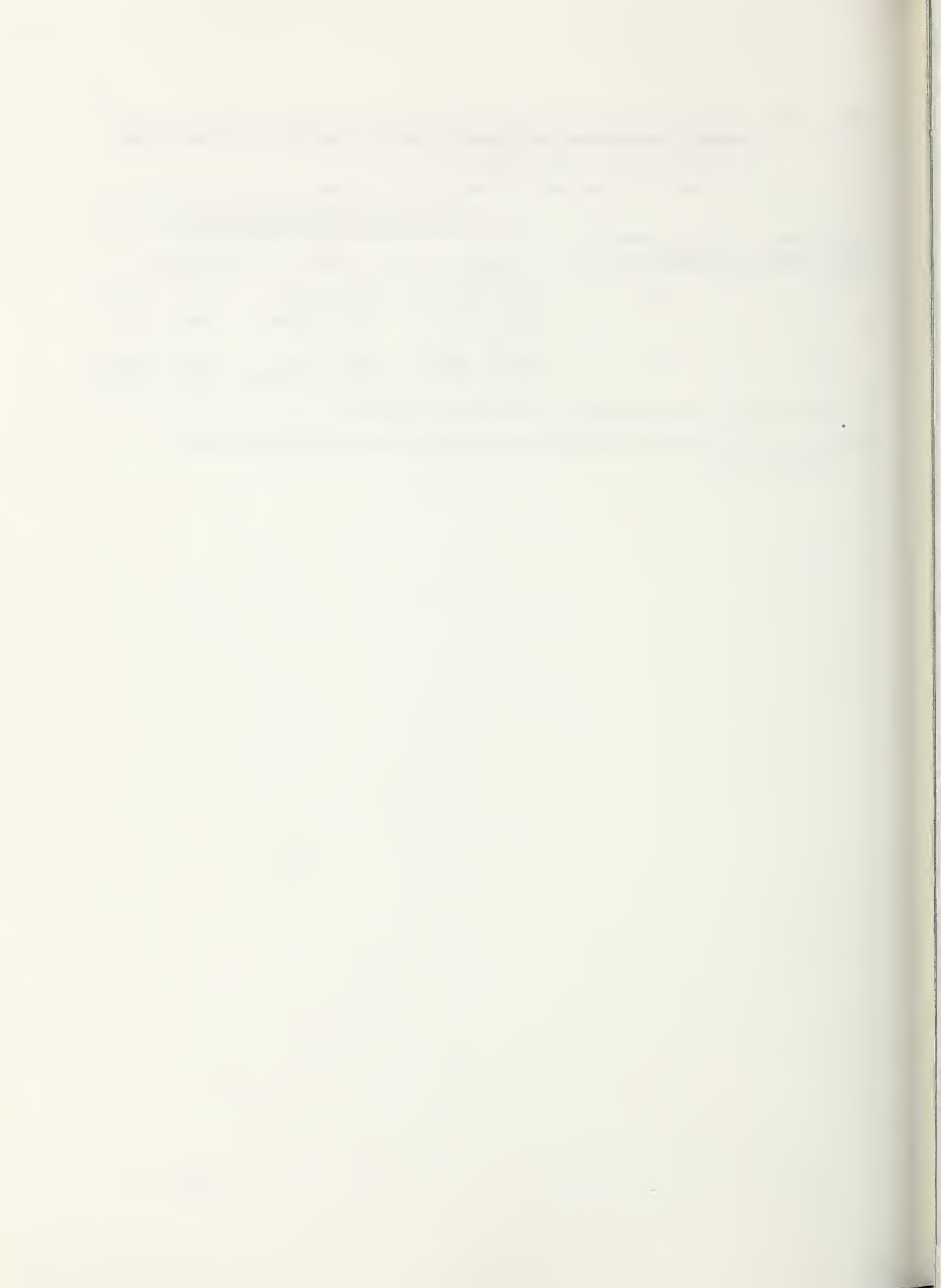
ab Any mean comparison with the same letters is not different ( $P > .05$ ). Mean ± S.E. T = temperature abused, N = not temperature abused. Includes only +20°F final storage temperature product.



Table 259. Interaction effect of storage time (nine, twelve months), initial storage temperature and freezing rate on evaporative loss during cooling of cooked beef roasts

Evaluation time, months	Initial storage temperature, °F	Freezing rate, hours to 0°F		
		24	48	96
9	-10	3.67 $\pm$ .10abcd	3.39 $\pm$ .10cd	3.73 $\pm$ .10abcd
12		3.24 $\pm$ .10d	3.85 $\pm$ .10abc	4.00 $\pm$ .10a
9	0	3.40 $\pm$ .10bcd	3.92 $\pm$ .10ab	3.76 $\pm$ .10abcd
12		3.32 $\pm$ .10d	3.59 $\pm$ .10abcd	3.65 $\pm$ .10abcd

abcd Any mean comparison with the same letters is not different ( $P > .05$ ).  
Mean  $\pm$  S.E.





differences were not found at nine months or with the use of 0°F initial temperature. Tables 260-266 present information regarding the time required to drop to 50°C in cooling and thus are largely of academic interest.

General information pertaining to percent moisture in raw beef roasts is shown in Table 267. As would be expected, advances in storage time and the use of +20°F final storage temperature both reduced moisture percent. There was some indication (although not significant by HSD) that immediately following freezing, faster freezing rates produced less moisture in the roasts (Table 268). Following twelve months of storage, +20°F final storage temperature produced lower moisture percentages than -10 and 0°F (Table 269). Also, at twelve months storage, temperature abuse produced less moisture in the product than not abusing the product (Table 270). As expected, increases in storage time produced a reduction in moisture level, in the roasts (Table 271). However, in specific initial-final temperature combination comparisons at six, nine and twelve months, many were not lower in moisture than that observed immediately following freezing (Table 272). Although not significant ( $P>.05$ ), twelve months of storage produced an increase in moisture percent only for roasts frozen to 0°F in 24 hr (Table 273). Final storage at 0°F produced more moisture in roasts than +20°F storage following twelve months, but not at nine months (Table 274). Following twelve months storage, in evaluating various combinations of temperature abused and initial storage temperature, all combinations had less moisture in roasts than the use of 10°F with no abuse (Table 275).



Table 260. General table illustrating the time (min) for cooked roasts to cool following cooking from their highest point to 50°C throughout storage and according to final storage temperature and rate of freezing - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		62.47 + -	63.44 + -		60.12 + - 10.18
Immediately following freezing, 1 day		58.62 + -	61.72 + -	53.16 + - 10.53	56.71 + - 7.56
6 months	-10T	35.00 + -	59.15 + -	57.5 + -	43.70 + - 8.25
	0T	52.75 + -	45.07 + -	59.75 + -	43.87 + - 4.15
	20T	46.75 + -	56.45 + -	51.12 + -	54.57 + - 20.51
9 months	-10T	49.52 + -	52.90 + -	43.37 + -	50.50 + - 2.34
	0T	59.90 + -	59.47 + -	53.37 + -	48.62 + - 4.19
	20t	53.15 + -	61.02 + -	56.62 + -	52.87 + - 2.29
12 months	-10T	54.19 + -	50.72 + -	51.20 + -	56.75 + - 8.46
	0T	52.75 + -	49.70 + -	57.00 + -	53.12 + - 13.14
	20T	57.12 + -	73.77 + -	56.20 + -	60.25 + - 6.98
	20N	51.32 + -	49.12 + -	54.50 + -	50.75 + - 11.03

<sup>a</sup>Mean + S.D. T = temperature abused, N = not temperature abused.

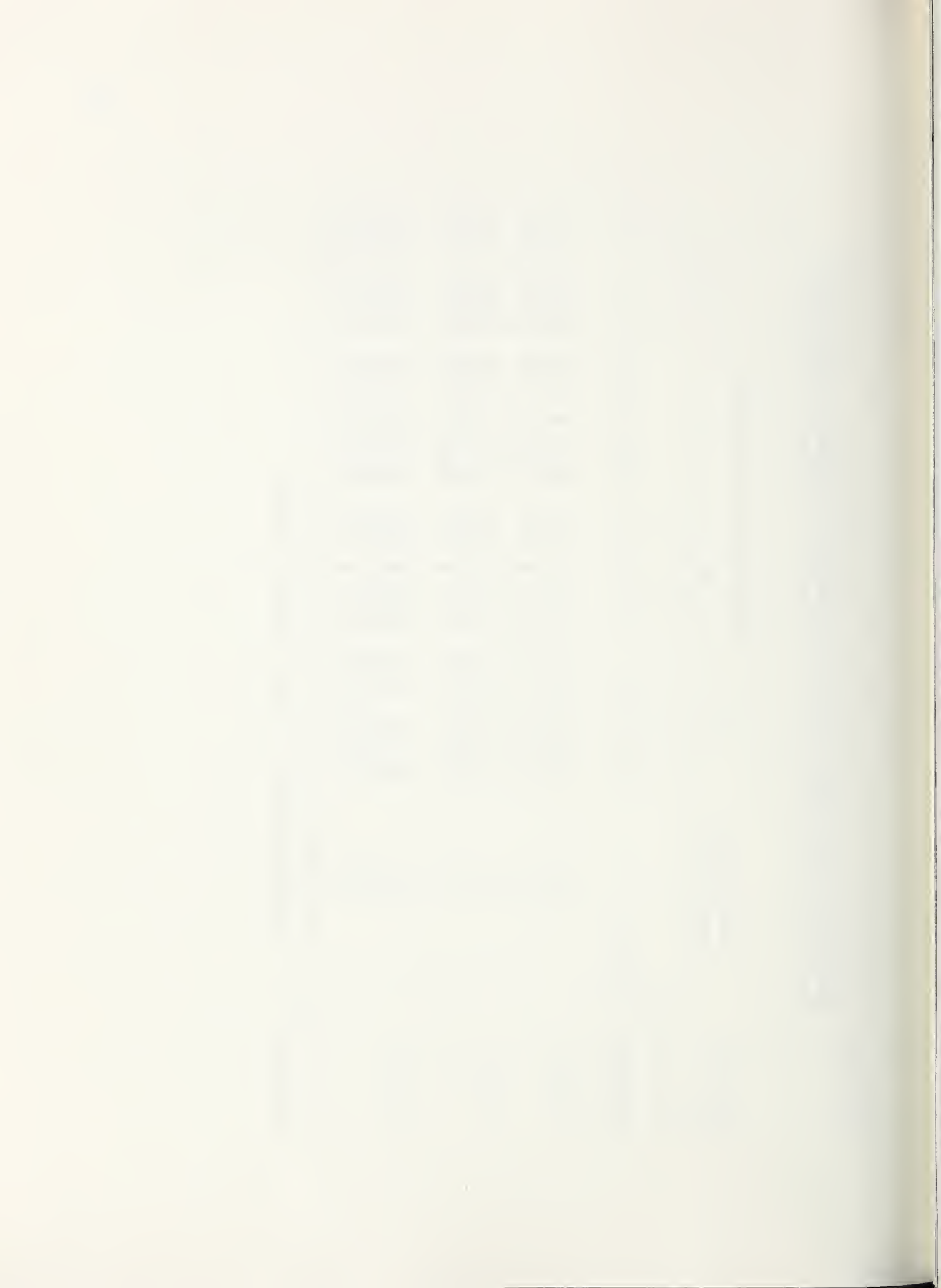


Table 261. Interaction effect of initial storage temperature, final storage temperature and rate of freezing on the time for roasts to cool following cooking from their highest point to 50C following nine months of storage

Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
-10	-10	54.0	47.30 + 5.15ab	33.25 + 5.15b	49.50 + 5.15ab
	0	60.15 + 5.15ab	47.30 + 5.15ab	55.50 + 5.15ab	48.75 + 5.15ab
	20	46.15 + 5.15ab	63.55 + 5.15ab	54.25 + 5.15ab	51.75 + 5.15ab
0	-10	45.05 + 5.15ab	58.50 + 5.15ab	53.50 + 5.15ab	51.50 + 5.15ab
	0	59.65 + 5.15ab	71.65 + 5.15a	51.25 + 5.15ab	48.50 + 5.15ab
	20	60.15 + 5.15ab	58.50 + 5.15ab	59.00 + 5.15ab	54.00 + 8.14ab

abc Any mean comparison with the same letters is not different ( $P > .05$ ). Mean + S.E.



Table 262. Effect of final storage temperature on time (min) required during cooling of cooked beef roasts to reach 50°C<sup>a</sup> following twelve months storage

Final storage temperature, °F		
-10	0	20
53.22 ± 2.88	53.14 ± 2.45	61.84 ± 2.45

<sup>a</sup>Difference significant (P<.05) by analysis of variance, but not by HSD.  
Mean ± S.E.

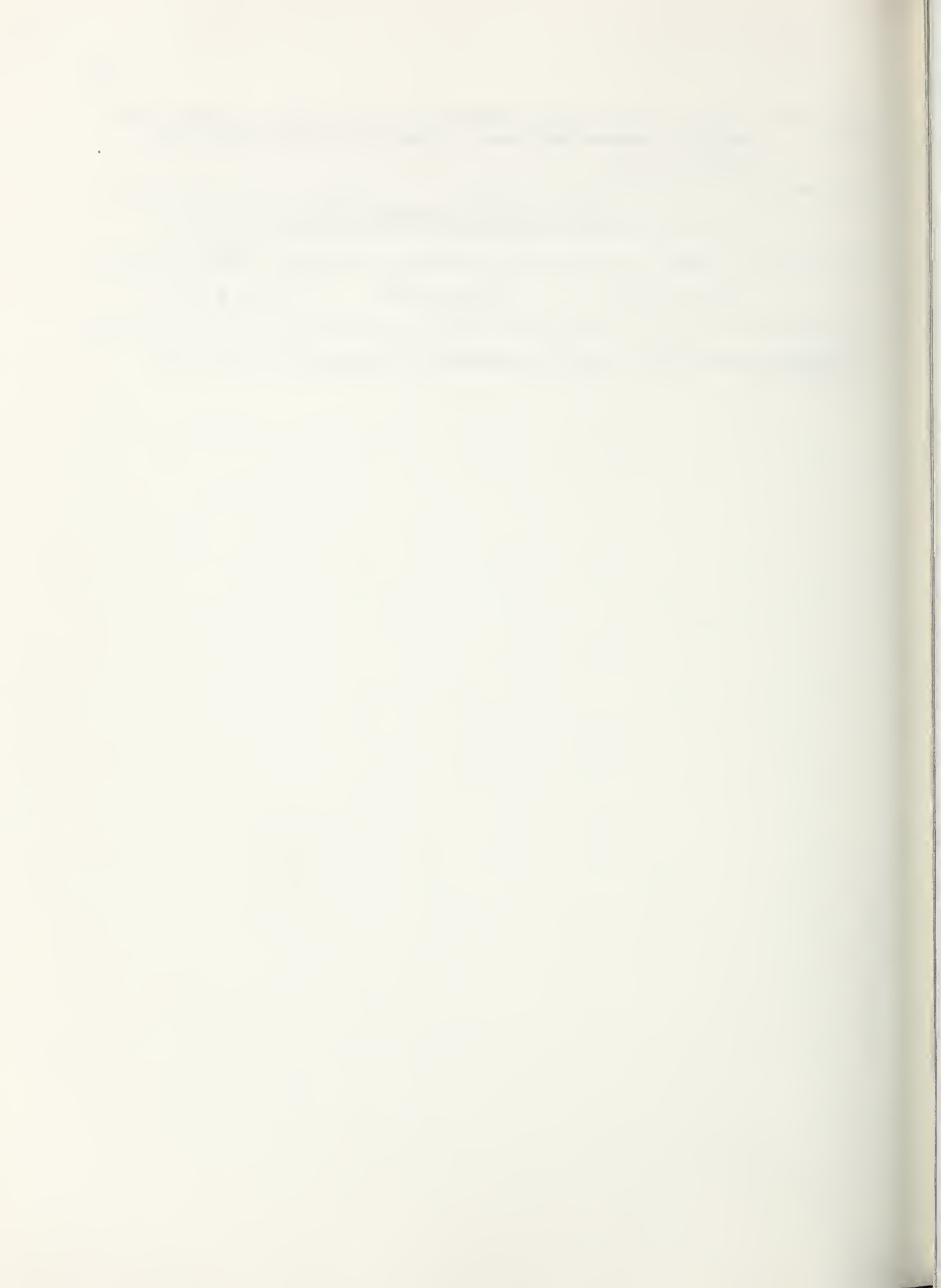




Table 263. Effect of initial storage temperature on time (min) required in cooling cooked beef roasts to 50°C following twelve months storage

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<u>Initial storage temperature, °F</u>	
<u>-10</u>	<u>0</u>
59.44 $\pm$ 1.80a	53.82 $\pm$ 1.80b

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ab Difference between means significant ( $P < .05$ ). Mean  $\pm$  S.E.



Table 264. Interaction effect of temperature abuse and rate of freezing on time (min) following cooking to reach 50°F for cooked roasts following twelve months storage

Temperature abuse	Freezing Rate, hours to 0°F			
	24	48	72	96
T	57.12 $\pm$ 3.59ab	73.77 $\pm$ 3.59a	56.2 $\pm$ 3.59ab	60.25 $\pm$ 3.59ab
N	51.32 $\pm$ 3.59b	49.12 $\pm$ 3.59b	54.5 $\pm$ 3.59b	50.75 $\pm$ 3.59b

ab Any mean comparison with different letters is different ( $P < .05$ ).  
Mean  $\pm$  S.E. T = temperature abused, N = not temperature abused.  
Includes only +20°F final storage.



Table 265. Interaction effect of storage time (nine, twelve months) and initial storage temperature on time required for cooked beef roasts to reach 50°F following cooking

Evaluation time, months	Initial storage temperature, °F	
	-10	0
9	50.95 $\pm$ 1.45b	55.33 $\pm$ 1.57ab
12	58.22 $\pm$ 1.57a	54.70 $\pm$ 1.57ab

ab Any mean comparison with the same letter is not different ( $P > .05$ ).  
Mean  $\pm$  S.E.

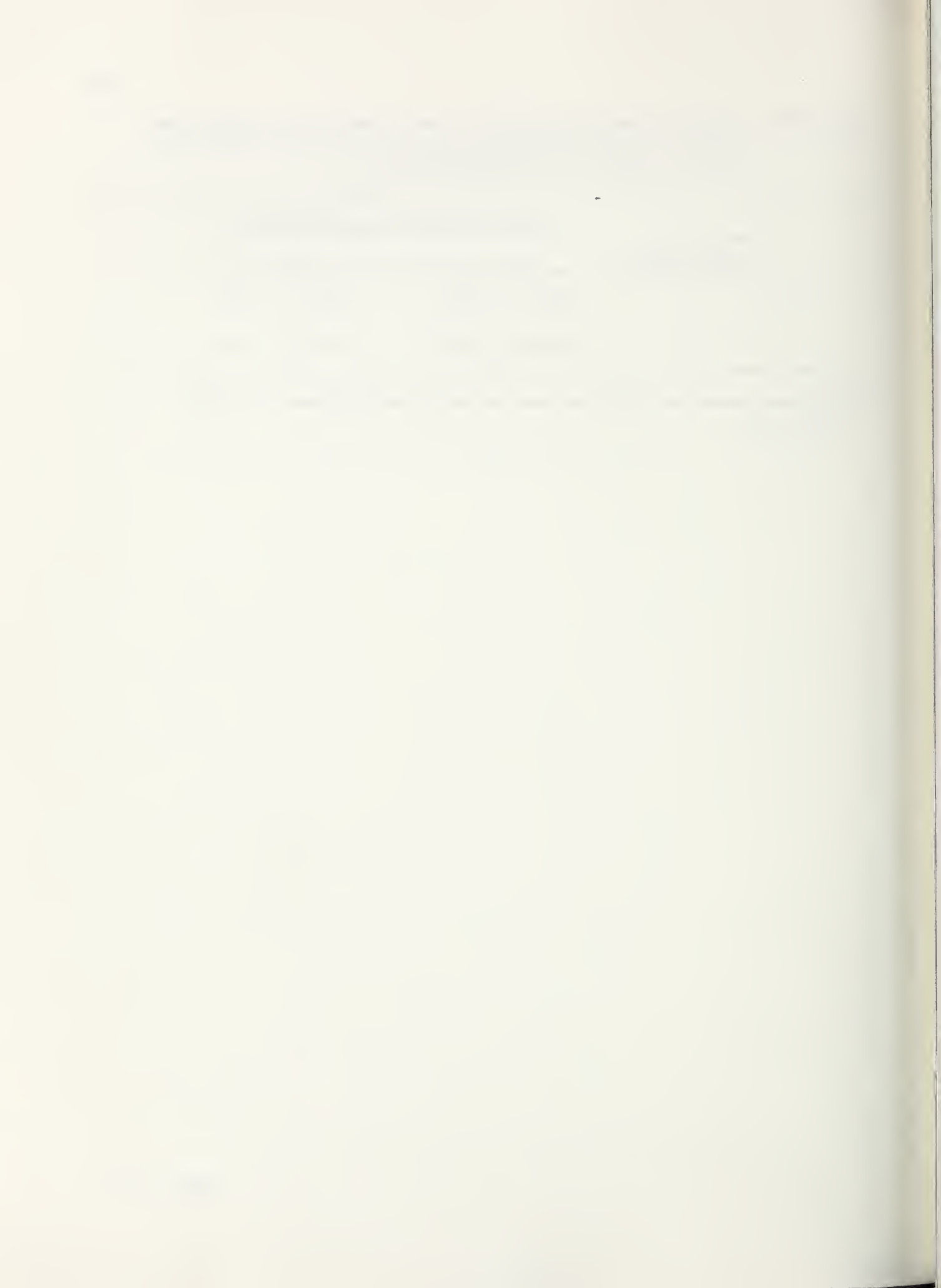


Table 266. Interaction effect of storage time (nine, twelve months) and final storage temperature on time required to reach 50°F following cooking of beef roasts

Evaluation time	Final storage temperature, °F		
	-10	0	+20
9	49.07 $\pm$ 1.78b	55.3 $\pm$ 1.78ab	55.01 $\pm$ 2.00ab
12	54.39 $\pm$ 2.18ab	53.14 $\pm$ 1.78ab	61.84 $\pm$ 1.78a

ab Any mean comparison with the same letters is not different ( $P > .05$ ).  
Mean  $\pm$  S.E.





Table 267. General table illustrating the percent moisture in raw beef roasts throughout storage and according to final storage temperature and rate of freezing - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		73.73 ± 1.19	72.53 ± 1.02	73.45 ± 1.29	73.86 ± 1.67
Immediately after freezing, 1 day		72.52 ± 1.4	72.92 ± .72	73.59 ± 1.24	74.04 ± 1.0
6 months	-10T	72.44 ± 2.29	72.35 ± .85	71.0 ± 1.88	72.31 ± 1.79
	0T	71.43 ± 1.59	71.57 ± 1.02	69.9 ± 1.98	71.57 ± .97
	20T	71.6 ± 1.63	72.39 ± .82	70.78 ± 1.51	72.2 ± 1.59
9 months	-10T	71.53 ± 1.8	72.56 ± .93	72.55 ± .67	71.09 ± 1.03
	0T	71.12 ± .94	72.4 ± 1.13	70.2 ± 2.69	71.54 ± 1.09
	20T	70.24 ± 1.81	71.93 ± 1.91	71.61 ± .78	71.19 ± .89
12 months	-10T	72.11 ± 1.38	72.70 ± 1.51	70.44 ± 1.45	72.06 ± 1.2
	0T	73.62 ± .45	72.18 ± 1.12	70.84 ± 1.17	72.76 ± .29
	20T	70.96 ± 1.07	70.3 ± .90	69.7 ± 1.47	70.1 ± 1.87
	20N	71.47 ± 1.22	71.62 ± 2.09	73.24 ± .54	69.51 ± 1.65

<sup>a</sup>Means ± S.D.; T = Temperature abused; N = Not temperature abused.

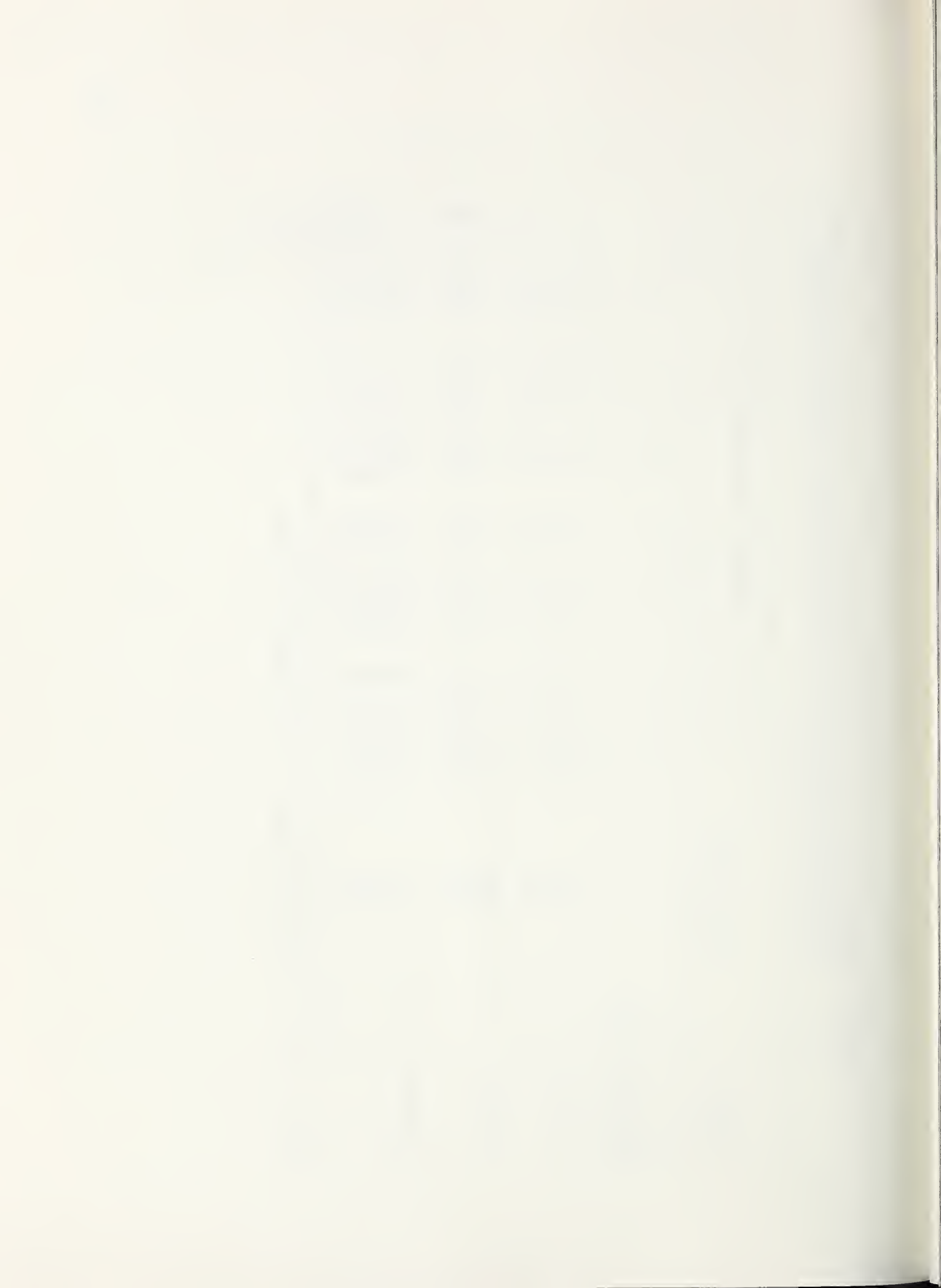


Table 268. Effect of freezing rate on percent moisture in raw beef roasts immediately following freezing<sup>a</sup>

Freezing rate, hours to 0°F			
24	48	72	96
72.52 ± .4	72.92 ± .4	73.59 ± .4	74.04 ± .4

<sup>a</sup>Difference due to freezing rate significant ( $P < .05$ ) by analysis of variance, but not by HSD.

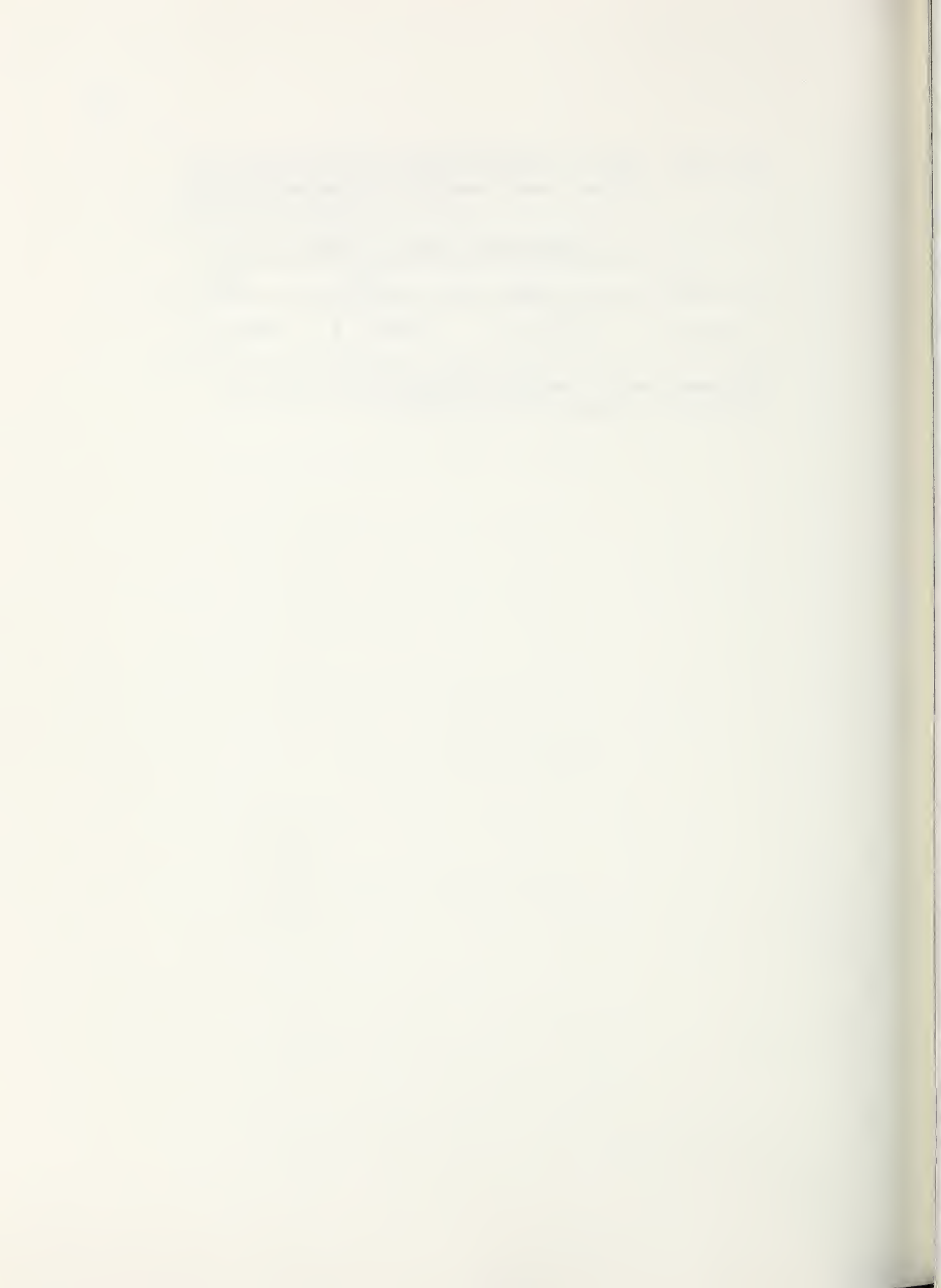


Table 269. Effect of final storage temperature on percent moisture in raw beef roasts following twelve months storage

Final storage temperature, °F		
-10	0	20
71.83 $\pm$ .28a	72.35 $\pm$ .28a	70.27 $\pm$ .28b

ab Means on the same line with different letters are different ( $P < .05$ ); Mean  $\pm$  S.E.



Table 270. Effect of temperature abuse on percent moisture in raw beef roasts following twelve months storage

Temperature Abuse	
T	N
70.27 $\pm$ .36b	71.46 $\pm$ .36a

ab Difference between means significant ( $P < .05$ ). Mean  $\pm$  S.E. T = temperature abused, N = not temperature abused. Includes only +20°F final temperature stored product.

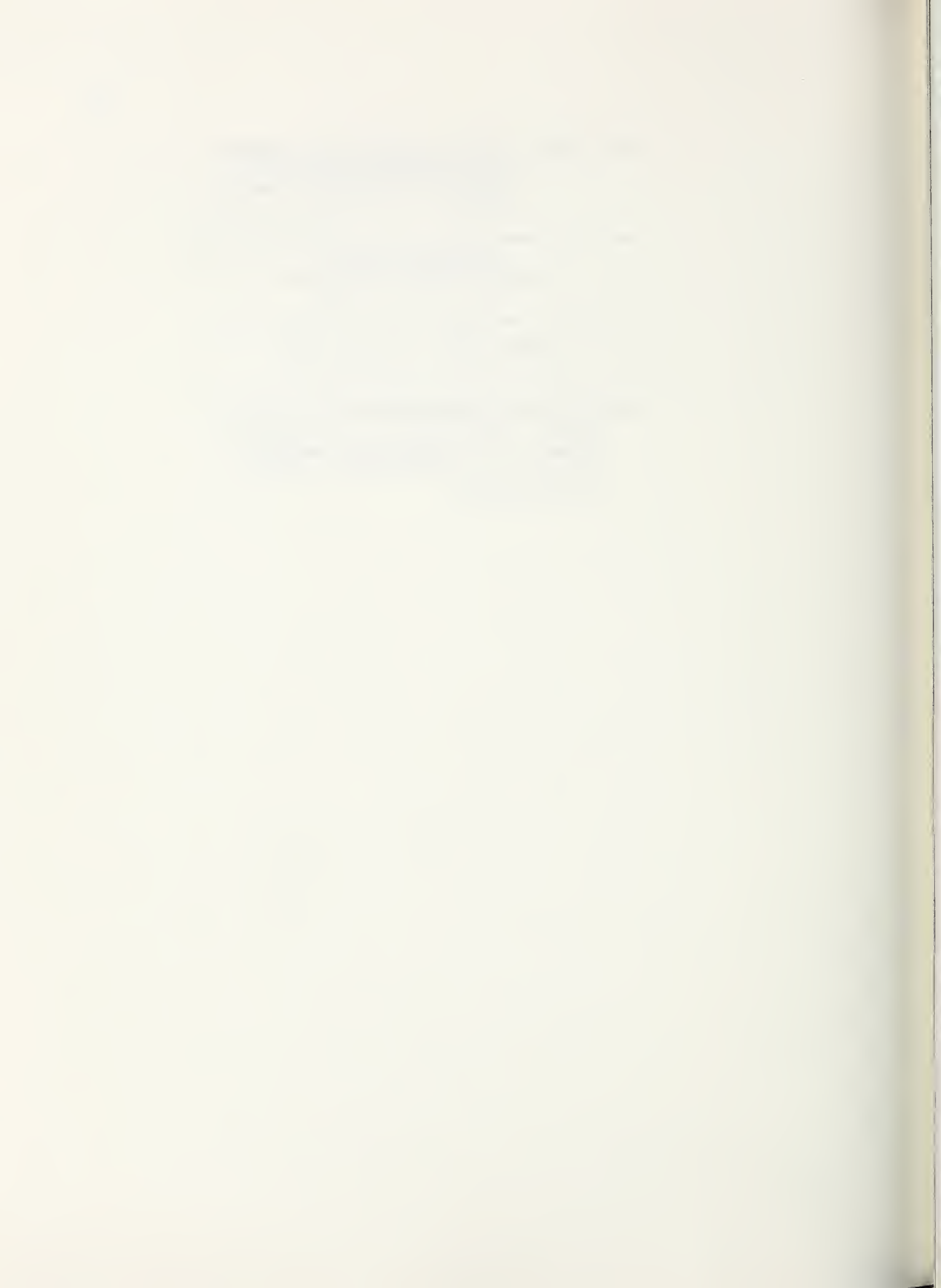




Table 271. Effect of various storage time comparisons on percent moisture in raw beef roasts

Evaluation Time	
Immediately following freezing, 1 day	6 months
73.06 $\pm$ .35a	71.63 $\pm$ .35b
Immediately following freezing, 1 day	9 months
73.06 $\pm$ .42a	71.5 $\pm$ .42b
Immediately following freezing, 1 day <sup>c</sup>	12 months <sup>c</sup>
73.06 $\pm$ .32a	71.48 $\pm$ .32b
Immediately following freezing, 1 day <sup>d</sup>	12 months <sup>d</sup>
73.26 $\pm$ .23a	70.9 $\pm$ .23b

ab Differences between means on the same line are significant ( $P < .05$ ); Mean  $\pm$  S.E.

<sup>c</sup>Includes only temperature abused product at twelve months.

<sup>d</sup>Includes only +20°F final storage temperature product at twelve months.

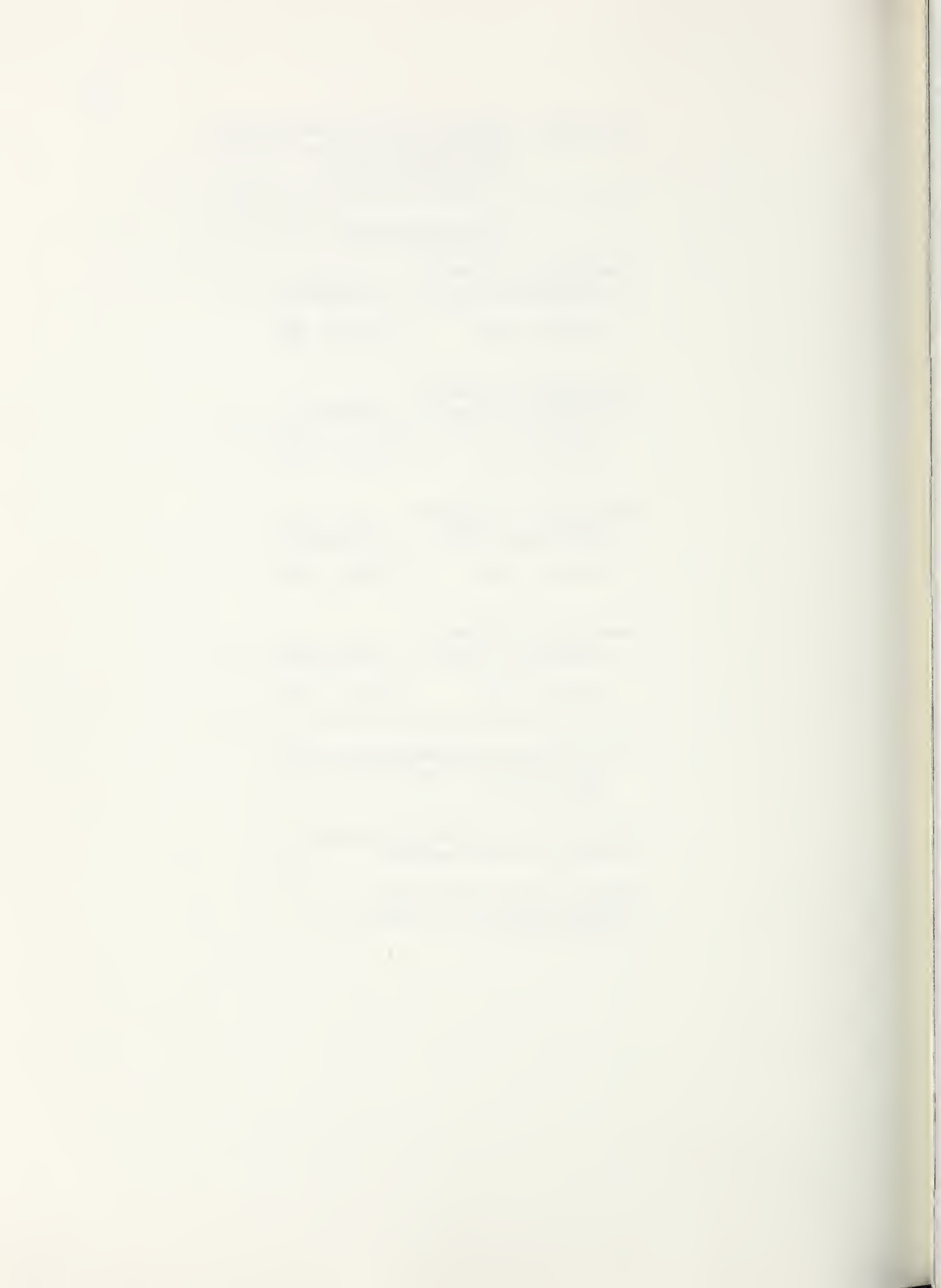


Table 272. Effects of various storage time comparisons with time = immediately following freezing on percent moisture in raw beef roasts

		Storage Times			
		6 Months			
Immediately following freezing, 1 day	Initial Storage temperature, °F =				
	Final Storage temperature, °F =				
		-10	0	20	-10
73.06 ± .32a		72.28 ± .56ab	70.97 ± .56b	71.63 ± .56ab	71.77 ± .56ab
					71.27 ± .56ab
					71.86 ± .56ab
					20
		9 Months			
73.06 ± .4a		71.89 ± .62ab	71.85 ± .62ab	71.36 ± .62ab	71.97 ± .62ab
					70.78 ± .62b
					71.13 ± .62ab
		12 Months			
73.06 ± .32a		71.54 ± .55abc	72.45 ± .55ab	70.56 ± .55bc	72.12 ± .55ab
					72.25 ± .55ab
					69.97 ± .55c

abc Means on the same line with the same letters are not different ( $P > .05$ ); Mean ± S.E.



Table 273. Interaction effect of storage time (nine, twelve months) and rate of freezing on percent moisture in raw beef roasts<sup>a</sup>

Evaluation Time, months	Freezing rate, hours to 0°F			
	24	48	72	96
9	70.96 $\pm$ .43	72.3 $\pm$ .43	71.45 $\pm$ .43	71.28 $\pm$ .43
12	72.23 $\pm$ .43	71.73 $\pm$ .43	70.33 $\pm$ .43	71.64 $\pm$ .43

<sup>a</sup>Interaction significant ( $P < .05$ ) by analysis of variance, but not by HSD..

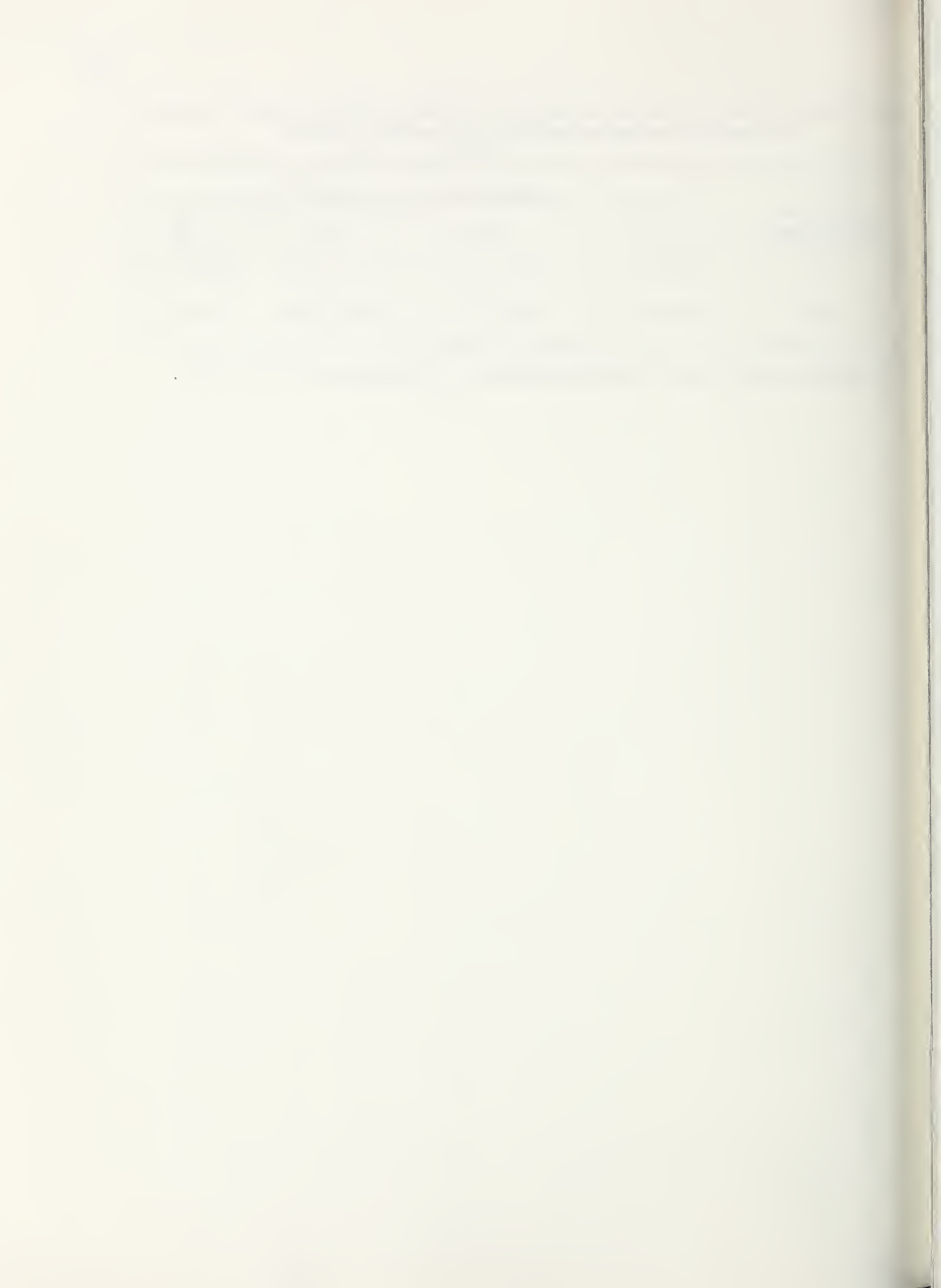


Table 274. Interaction effect of storage time (nine, twelve months) and final storage temperature on percent moisture in raw beef roasts

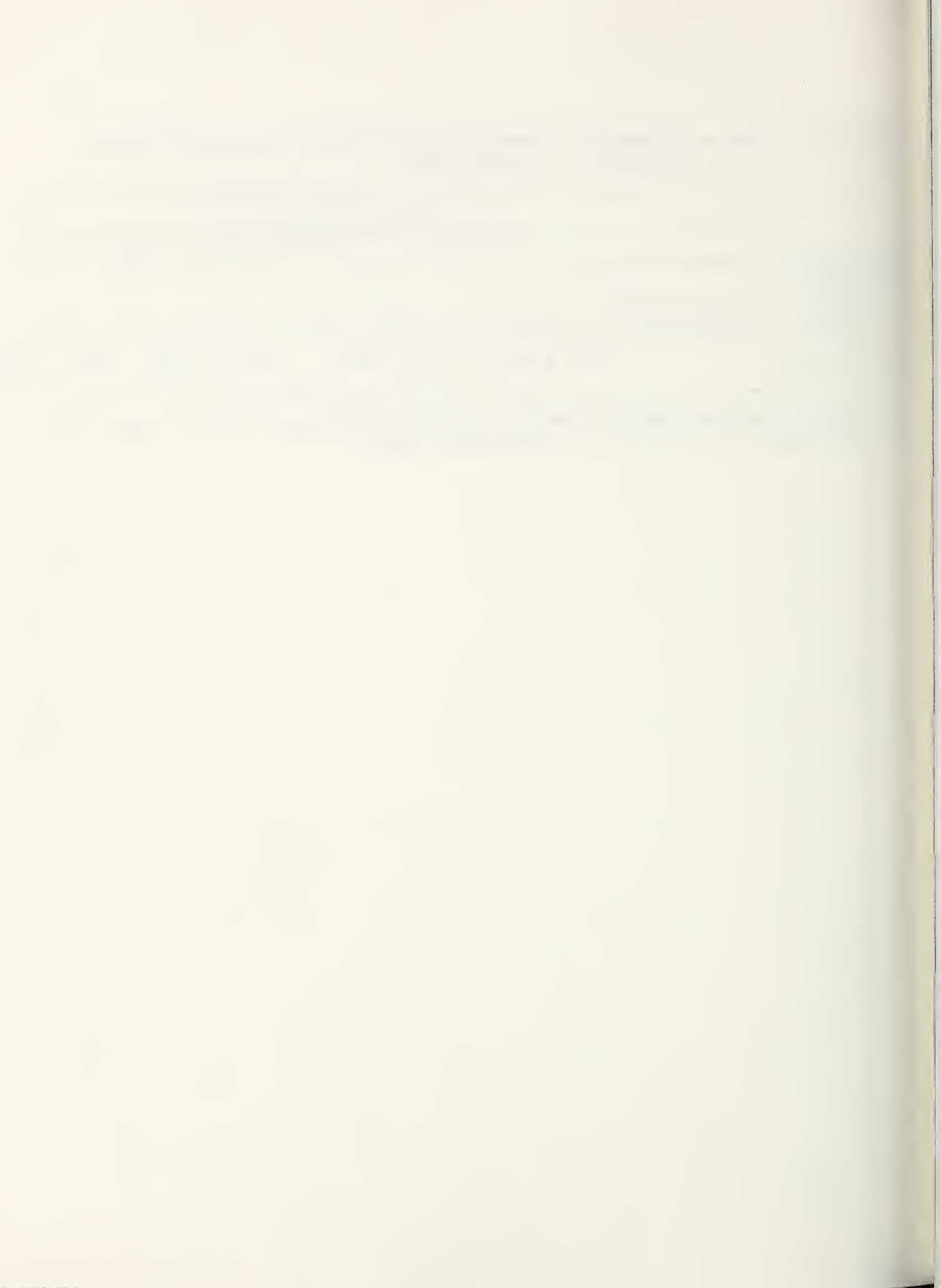
Evaluation Time, months	Final storage temperature, °F		
	-10	0	20
9	71.93 $\pm$ .37a	71.31 $\pm$ .37ab	71.24 $\pm$ .37ab
12	71.83 $\pm$ .37ab	72.35 $\pm$ .37a	70.27 $\pm$ .37b

ab Any mean comparisons with the same letters are not different ( $P > .05$ ); Mean  $\pm$  S.E.









As expected, the opposite situation to percent moisture was noted for percent fat (Table 276) where the use of storage at +20°F final storage elevated the percent fat in raw roasts. However, freezing in itself produced reductions in fat level for all rates except 0°F in 24 hr; however, this difference was only significant for the 0°F in 72 hr rate (Table 277). After twelve months of storage, roasts stored finally at +20°F had higher fat percentages than roasts stored at 0°F (Table 278). Fat values went down as a result of freezing, but rose with twelve months of storage (Table 279).

General values for percent moisture in cooked roasts are shown in Table 280. Consistent patterns and trends do not appear evident except for the more elevated values for roasts held at 0°F final temperature after twelve months storage regardless of freezing rate. Freezing rate did not affect cooked roast moisture values following six months storage, except when adjustments were made to account for differences before freezing. Then roasts frozen to 0°F in 96 hr had more moisture in cooked roasts than roasts frozen to 0°F in 48 hr (Table 281). At twelve months of storage, for roasts initially stored at -10°F, those finally held at 0°F had more moisture than those stored at -10°F (Table 282). Freezing in itself significantly ( $P < .05$ ) reduced moisture in cooked roasts only for those frozen to 0°F in 24 hr (Table 283). Following twelve months of storage, temperature abuse seemed to elevate moisture in cooked roasts for all rates but 0°F in 96 hr (Table 284).

Both six and twelve months of storage produced increases in percent moisture in cooked roasts (Table 285). Also, twelve-month-stored roasts had more than nine-month-stored roasts (Table 286). In comparing the



Table 276. General table illustrating the percent fat in raw beef roasts throughout storage and according to final storage temperature and rate of freezing - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		4.39 + 1.56	5.65 + 1.04	4.81 + 1.44	3.63 + 1.57
Immediately after freezing, 1 day		5.04 + 2.0	3.97 + 1.29	3.66 + 1.46	2.86 + 1.09
6 months	-10T	4.08 + 1.51	3.91 + .44	4.85 + 2.64	4.2 + 1.85
	0T	5.45 + 1.91	4.17 + 1.29	6.16 + 2.42	4.38 + 1.43
	20T	5.76 + 1.63	3.03 + .42	4.54 + 1.9	3.67 + 1.63
9 months	-10T	4.82 + 2.43	2.69 + .93	3.46 + .91	5.19 + 2.11
	0T	5.4 + .87	4.04 + 1.55	6.69 + 2.99	4.31 + 1.79
	20T	5.56 + 1.64	3.69 + 1.21	3.78 + .43	4.13 + 1.23
12 months	-10T	5.33 + 2.41	3.62 + 1.68	5.62 + 1.72	2.55 + 1.08
	0T	3.39 + .62	3.87 + 1.39	5.48 + 1.48	2.8 + .51
	20T	5.84 + 2.26	4.55 + .25	6.17 + 1.75	5.05 + 1.99
	20N	4.27 + 1.48	4.64 + 2.51	2.65 + .50	5.94 + 1.98

<sup>a</sup>Mean + S.D.; T = Temperature abused; N = Not temperature abused.



Table 277. Interaction effect of storage time (immediately before freezing, immediately following freezing) and rate of freezing on percent fat in raw beef roasts

Evaluation Time	Freezing rate, hours to 0°F			
	24	48	72	96
Before freezing	4.39 $\pm$ .4ab	5.65 $\pm$ .4a	4.81 $\pm$ .4a	3.63 $\pm$ .4b
Immediately following freezing, 1 day	5.04 $\pm$ .4a	3.97 $\pm$ .4ab	3.66 $\pm$ .4b	2.86 $\pm$ .4b

ab Any mean comparison with different letters is different ( $P < .05$ ); Mean  $\pm$  S.E.





Table 278. Effect of final storage temperature on percent fat in raw beef roasts following twelve months storage

Final storage temperature, °F		
-10	0	20
4.28 $\pm$ .35ab	3.88 $\pm$ .35b	5.40 $\pm$ .35a

ab Means on the same line with different letters are different ( $P < .05$ ); Mean  $\pm$  S.E.



Table 279. Effect of various storage time comparisons on percent fat in raw beef roasts

Evaluation Time	
Before freezing	Immediately following freezing, 1 day
4.62 $\pm$ .20a	3.88 $\pm$ .20b
Immediately following freezing, 1 day	12 months
3.88 $\pm$ .29b	4.88 $\pm$ .29a

ab Difference between means significant ( $P < .05$ ); Mean  $\pm$  S.E.



Table 280. General table illustrating the percent moisture in cooked beef roasts throughout storage times and according to final storage temperature and rate of freezing - no statistical analysis<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0° F			
		24	48	72	96
Before freezing		64.91 $\pm$ 1.76	61.2 $\pm$ 3.25	63.33 $\pm$ 1.39	63.62 $\pm$ 1.68
Immediately after freezing, 1 day		61.66 $\pm$ 1.2	62.02 $\pm$ 1.46	62.26 $\pm$ 1.34	60.53 $\pm$ 2.68
6 months	-10T	64.27 $\pm$ 2.59	61.26 $\pm$ 1.05	62.42 $\pm$ 1.56	64.53 $\pm$ 1.77
	0T	63.91 $\pm$ 1.67	61.55 $\pm$ 2.08	62.21 $\pm$ 1.83	64.71 $\pm$ 1.03
	20T	62.89 $\pm$ 1.86	60.56 $\pm$ 2.04	64.03 $\pm$ 2.59	62.78 $\pm$ 2.11
9 months	-10T	58.47 $\pm$ .91	61.46 $\pm$ 2.11	61.7 $\pm$ .60	62.9 $\pm$ 2.45
	0T	60.83 $\pm$ 1.6	61.61 $\pm$ 2.23	63.65 $\pm$ 3.63	63.64 $\pm$ 2.47
	20T	60.15 $\pm$ 1.04	60.15 $\pm$ 1.67	61.51 $\pm$ 2.63	61.97 $\pm$ 2.31
12 months	-10T	62.91 $\pm$ 1.72	64.93 $\pm$ 1.65	61.52 $\pm$ 1.99	62.41 $\pm$ 1.73
	0T	63.08 $\pm$ 2.03	65.0 $\pm$ .90	64.52 $\pm$ 1.17	65.19 $\pm$ 1.64
	20T	62.0 $\pm$ 1.18	63.13 $\pm$ .34	63.38 $\pm$ 2.61	60.99 $\pm$ 2.83
	20N	61.32 $\pm$ .89	59.78 $\pm$ 1.59	60.93 $\pm$ 1.11	62.93 $\pm$ 1.74

<sup>a</sup>Mean  $\pm$  S.D. T = Temperature abused; N = not temperature abused.

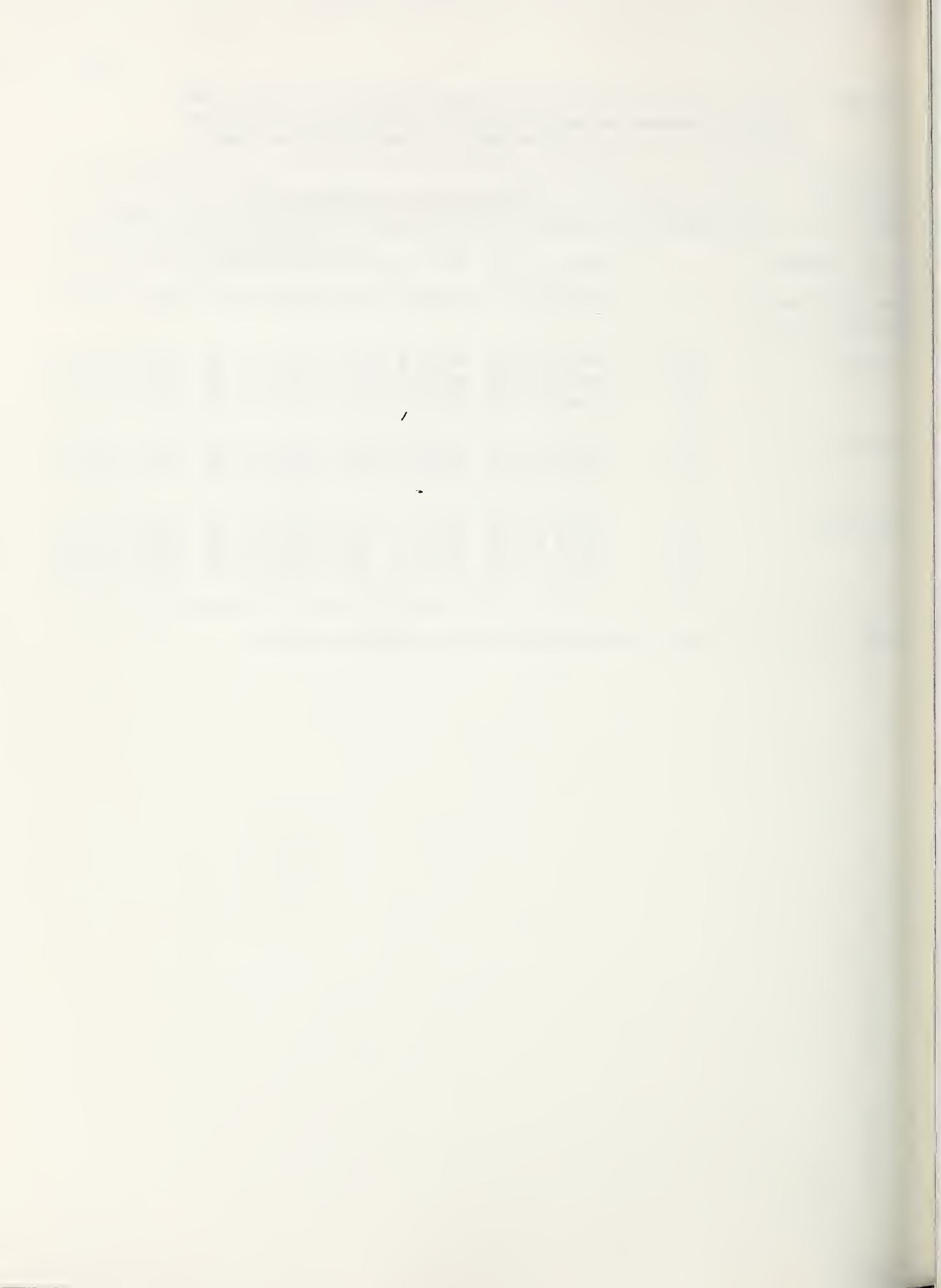


Table 281. Effect of freezing on percent moisture in cooked beef roasts following six months storage - data adjusted for differences prior to freezing

Freezing rate, hours to 0°F			
24	48	72	96
63.46 $\pm$ .55ab	61.42 $\pm$ .55b	62.74 $\pm$ .55ab	63.95 $\pm$ .55a

ab Means on the same line with the same letters are not different ( $P>.05$ ).  
Mean  $\pm$  S.E.





Table 282. Interaction effect of final storage temperature and initial storage temperature on percent moisture in cooked beef roasts following twelve months of storage

Final storage temperature, °F	Initial storage temperature, °F	
	-10	0
-10	62.15 $\pm$ .63b	63.74 $\pm$ .63ab
0	65.33 $\pm$ .63a	63.57 $\pm$ .63ab
20	63.06 $\pm$ .63ab	61.69 $\pm$ .63b

ab Any mean comparisons with the same letter are not different.  
Mean  $\pm$  S.E.



Table 283. Interaction effect of storage time (before freezing, immediately following freezing) and rate of freezing on percent moisture in cooked beef roasts

Evaluation time	Freezing rate, hours to 0°F			
	24	48	72	96
Before freezing	64.91 $\pm$ .68a	61.20 $\pm$ .68b	63.33 $\pm$ .68ab	63.62 $\pm$ .68ab
Immediately after freezing, 1 day	61.66 $\pm$ .68b	62.02 $\pm$ .68ab	62.26 $\pm$ .68ab	60.53 $\pm$ .68b

ab Any mean comparison with the same letter is not different (P>.05). Mean  $\pm$  S.E.



Table 284. Interaction effect of temperature abuse and rate of freezing on percent moisture in cooked beef roasts following twelve months storage<sup>a</sup>

Temperature abuse	Freezing rate, hours to 0° F			
	24	48	72	96
T	62.00 $\pm$ .90	63.13 $\pm$ .90	63.38 $\pm$ .90	60.99 $\pm$ .90
N	61.32 $\pm$ .90	59.78 $\pm$ .90	60.93 $\pm$ .90	62.93 $\pm$ .90

<sup>a</sup> Interaction significant ( $P < .05$ ) by Analyses of Variance, but not by HSD.  
Mean  $\pm$  S.E. Includes only +20°F final storage temperature.



Table 285. Effect of various storage time comparisons on percent moisture in cooked beef roasts

<u>Evaluation time</u>	
<u>Immediately following freezing, 1 day</u>	<u>6 months</u>
61.61 $\pm$ .52a	62.93 $\pm$ .52b
<u>Immediately following freezing, 1 day</u>	<u>12 months</u>
61.81 $\pm$ .56a	63.45 $\pm$ .56b

ab Difference between means significant ( $P < .05$ ). Mean  $\pm$  S.E.





Table 286. Effect storage time on percent moisture in cooked beef roasts

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<u>Evaluation time, months</u>	
<u>9</u>	<u>12</u>
62.43 $\pm$ .55b	64.45 $\pm$ .55a

---

ab Difference between means significant ( $P < .05$ ). Mean  $\pm$  S.E.



various storage temperature combinations at twelve months, only roasts stored initially at  $-10^{\circ}\text{F}$  and finally at  $0^{\circ}\text{F}$  resulted in more moisture than that found immediately following freezing (Table 287). Only the  $0^{\circ}\text{F}$  in 48 hr freezing rate created an increase in percent moisture in cooked roasts between nine and twelve months of storage (Table 288). Adjusting for differences prefreezing still produced this difference, but also roasts frozen to  $0^{\circ}\text{F}$  in 72 hr had less cooked moisture at nine months than roasts frozen to  $0^{\circ}\text{F}$  in 48 hr and evaluated at twelve months (Table 289). Within the  $-10^{\circ}\text{F}$  initial storage temperature, roasts finally stored at  $-20^{\circ}\text{F}$  and evaluated at nine months possessed less water in cooked roasts than roasts stored twelve months and finally stored at  $0^{\circ}\text{F}$  (Table 290).

Percent fat values for cooked roasts tended to be erratic in regards to the project design variables, but were somewhat higher at nine and twelve months storage for roasts frozen to  $0^{\circ}\text{F}$  in 24 hr (Table 291). Before freezing, roasts selected for the  $0^{\circ}\text{F}$  in 48 hr rate had more fat in cooked roasts than those selected for the  $0^{\circ}\text{F}$  in 24 hr rate; the opposite was true following twelve months storage (Table 292). Removing prefreezing differences in percent fat resulted in some significant ( $P < .05$ ) interactions following storage. At six months, for roasts stored at  $-10^{\circ}\text{F}$  initially, those frozen to  $0^{\circ}\text{F}$  in 72 hr had more fat than roasts frozen to  $0^{\circ}\text{F}$  in 96 hr (Table 293). No such freezing rate effects were detected for the  $0^{\circ}\text{F}$  initial temperature. At twelve months, a similar initial temperature-freezing rate interaction was noted, but HSD tests for mean differences were all nonsignificant (Table 294). It would appear that there were some inconsistent effects between  $-10^{\circ}\text{F}$  and  $0^{\circ}\text{F}$  initial storage temperature on fat percentages depending on which freezing rate and storage time (nine, twelve months) were being evaluated (Tables 295, 296).



Table 287. Effect of storage time (immediately following freezing, twelve months) on percent moisture in cooked beef roasts

		Initial storage temperature, °F	
		-10	0
		Final storage temperature, °F	
Immediately following freezing, 1 day	-10	0	20
	62.21 ± .76b	65.39 ± .76a	63.12 ± .76ab
	61.81 ± .44b	62.21 ± .76b	65.39 ± .76a
		63.67 ± .76ab	63.51 ± .76ab
		61.62 ± .76b	

ab Means on the same line with the same letter are not different (P>.05).  
Mean ± S.E.



Table 288. Interaction effect of storage time (nine, twelve months), and rate of freezing on percent moisture in cooked beef roasts

Evaluation time, months	Freezing rate, hours to 0°F		
	48	72	96
9	61.08 $\pm$ .60b	62.29 $\pm$ .60ab	62.84 $\pm$ .60ab
12	64.35 $\pm$ .60a	63.14 $\pm$ .60a	62.86 $\pm$ .60ab

ab Any mean comparisons with the same letter are not different ( $P > .05$ ). Mean  $\pm$  S.E.

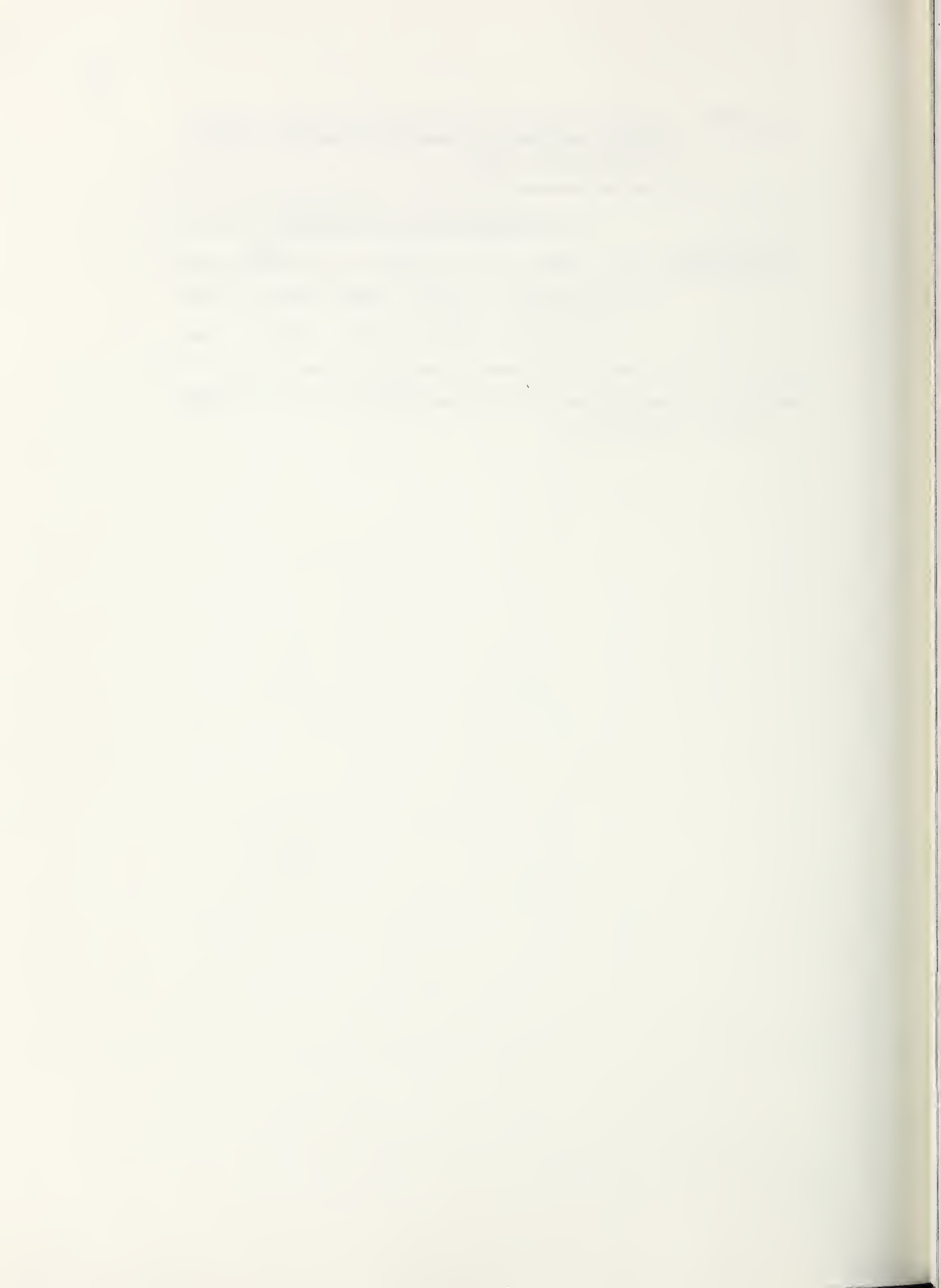




Table 289. Interaction effect of storage time (nine, twelve months) and rate of freezing on percent moisture in cooked beef roasts - data adjusted for differences prior to freezing

Evaluation time, months	Freezing rate, hours to 0°F		
	48	72	96
9	61.53 $\pm$ .60b	62.06 $\pm$ .60b	62.75 $\pm$ .60ab
12	64.81 $\pm$ .60a	62.91 $\pm$ .60ab	62.77 $\pm$ .60ab

ab Any mean comparison with the same letters is not different ( $P > .05$ )  
Mean  $\pm$  S.E.

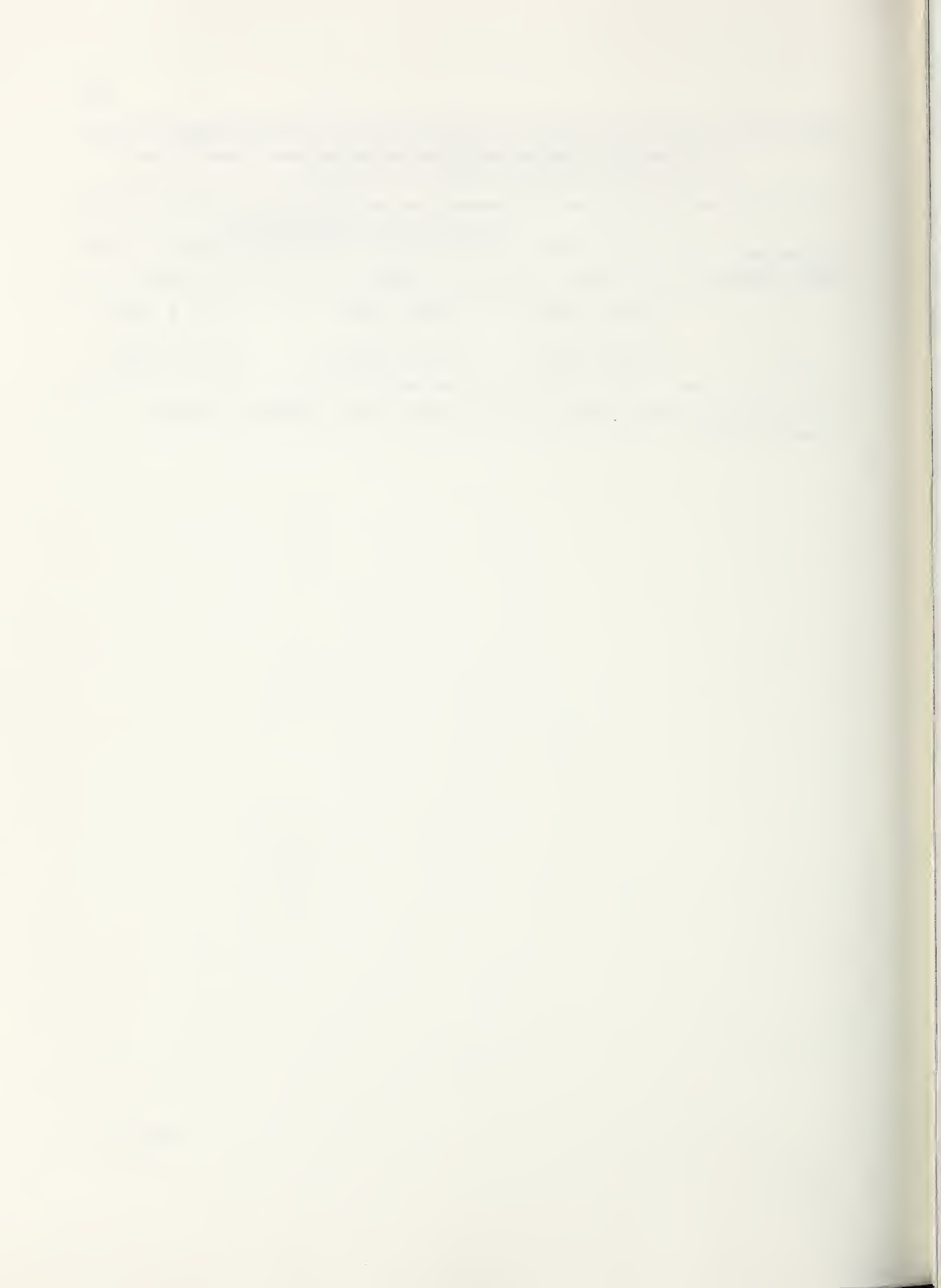


Table 290. Interaction effect of storage time (nine, twelve months), final storage temperature and initial storage temperature on percent moisture in cooked beef roasts

Evaluation time, months	Final storage temperature, °F	Initial storage temperature, °F	
		-10	0
9	-10	62.60 $\pm$ .84ab	61.44 $\pm$ .84ab
	0	62.92 $\pm$ .84ab	63.02 $\pm$ .84ab
	20	60.60 $\pm$ .84b	61.83 $\pm$ .84ab
12	-10	61.87 $\pm$ .84ab	64.03 $\pm$ .84ab
	0	65.62 $\pm$ .84a	64.19 $\pm$ .84ab
	20	63.26 $\pm$ .84ab	61.74 $\pm$ .84ab

ab Any mean comparisons with the same letters are not different ( $P > .05$ ).  
Mean  $\pm$  S.E.

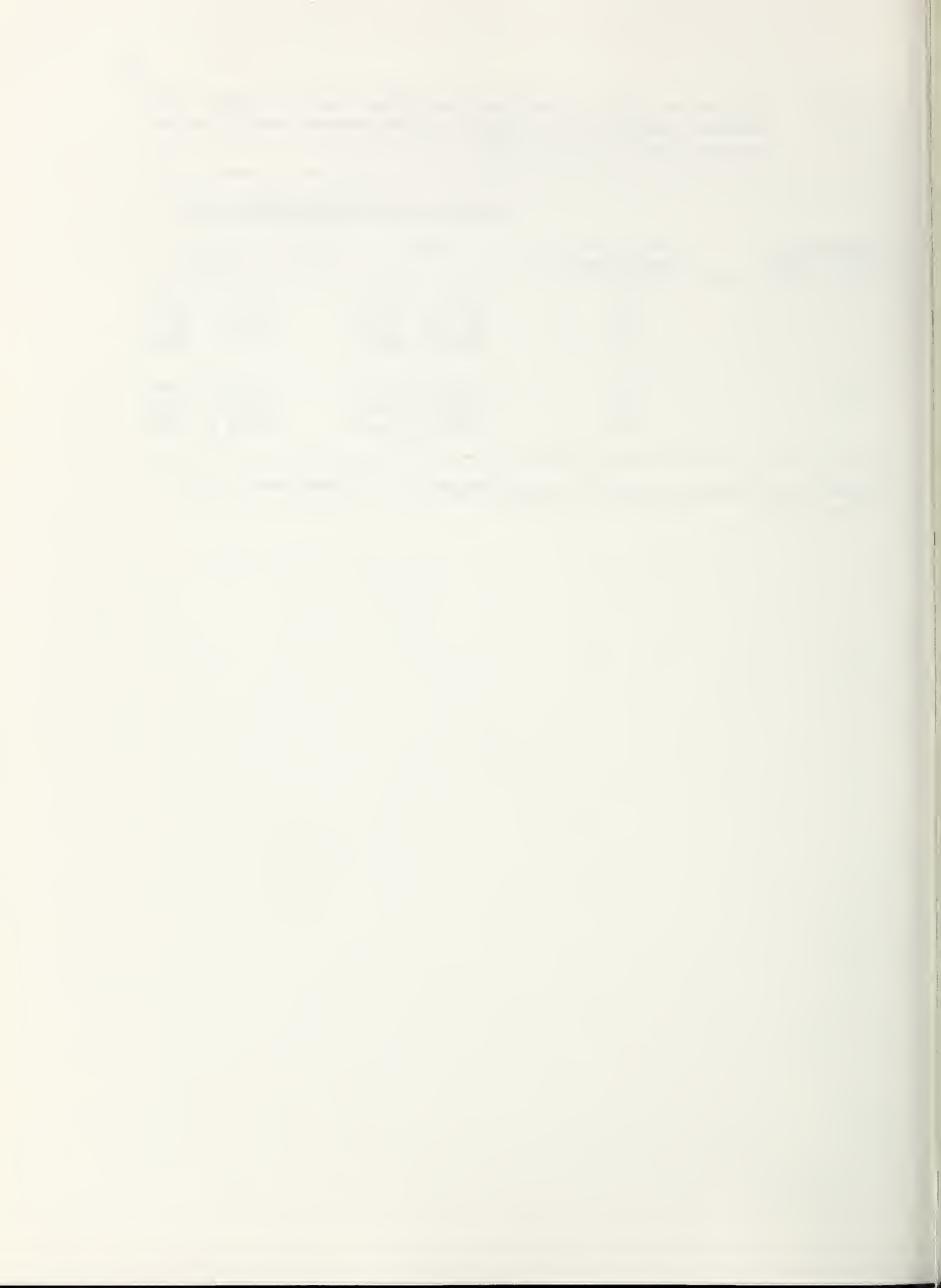


Table 291. General table illustrating the percent fat in cooked beef roasts throughout storage times and according to final storage temperature and rate of freezing - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0° F			
		24	48	72	96
Before freezing		5.16 ± 1.63	9.37 ± 4.01	6.32 ± 1.39	4.66 ± 1.62
Immediately after freezing, 1 day		7.22 ± 1.69	7.84 ± 2.16	5.65 ± 1.24	6.99 ± 3.01
6 months	-10T	5.75 ± 1.03	7.20 ± 2.07	5.89 ± 1.15	4.9 ± 2.21
	0T	5.97 ± 1.78	6.97 ± 2.84	6.29 ± 2.02	3.96 ± 1.83
	20T	5.92 ± .76	8.23 ± 3.2	5.72 ± .73	6.02 ± 1.86
9 months	-10T	9.61 ± 0.45	7.7 ± 2.92	6.76 ± 1.28	5.71 ± 2.92
	0T	7.38 ± 1.28	7.37 ± 2.29	6.18 ± 2.75	5.05 ± 2.41
	20T	7.28 ± 1.99	8.31 ± 2.15	7.12 ± 2.44	5.59 ± 2.36
12 months	-10T	7.45 ± 2.25	4.87 ± 1.66	7.35 ± 1.68	6.05 ± 1.25
	0T	8.08 ± 1.82	5.03 ± 1.19	4.46 ± 1.4	4.54 ± 1.16
	20T	8.45 ± 1.83	5.91 ± 2.84	4.75 ± 2.83	6.22 ± 4.1
	20N	8.25 ± 0.93	8.46 ± 2.25	8.05 ± 0.77	5.05 ± 3.29

<sup>a</sup>Mean ± S.D. T = Temperature abused; N = not temperature abused.



Table 292. Effect of freezing rate on percent fat in cooked beef roasts at several storage times

Evaluation time	Freezing rate, hours to 0° F			
	24	48	72	96
Before freezing <sup>c</sup>	5.15 ± .85b	9.37 ± .85a	6.32 ± .85ab	4.66 ± .85b
12 months	7.99 ± .63a	5.27 ± .63b	5.52 ± .63ab	5.60 ± .63ab

ab Means on the same line with the same letter are not different (P<.05).  
Mean ± S.E.

c Effect due to sampling time (or different animals) rather than freezing rate.





Table 293. Interaction effect of initial storage temperature and freezing rate on percent fat in cooked beef roasts following six months storage - data adjusted for differences prior to freezing

Initial storage temperature, °F	Freezing rate, hours to 0°F			
	24	48	72	96
-10	6.57 $\pm$ .57ab	5.54 $\pm$ .57ab	7.37 $\pm$ .57a	4.46 $\pm$ .57b
0	5.97 $\pm$ .57ab	7.26 $\pm$ .57ab	5.19 $\pm$ .57ab	6.69 $\pm$ .57ab

ab Any mean comparison with the same letters is not different ( $P > .05$ ).  
Mean  $\pm$  S.E.



Table 294. Interaction effect of initial storage temperature and rate of freezing on percent fat in cooked beef roasts following twelve months storage - data adjusted for differences prior to freezing<sup>a</sup>

Initial storage temperature, °F	Freezing rate, hours to 0°F			
	24	48	72	96
-10	8.17 $\pm$ 1.21	8.05 $\pm$ 1.21	6.10 $\pm$ 1.21	3.78 $\pm$ 1.21
0	9.11 $\pm$ 1.21	4.87 $\pm$ 1.21	6.73 $\pm$ 1.21	8.32 $\pm$ 1.21

<sup>a</sup> Interaction effect significant ( $P < .05$ ) by analysis of variance but not by HSD. Mean  $\pm$  S.E. Includes only +20°F final storage temperature.



Table 295. Interaction effect of storage time (nine, twelve months), initial storage temperature and rate of freezing on percent fat in cooked beef roasts<sup>a</sup>

Evaluation time, months	Initial storage temperature, °F	Freezing rate, hours to 0°F		
		48	72	96
9	-10	6.56 $\pm$ .91	7.84 $\pm$ .91	4.98 $\pm$ .91
	0	9.03 $\pm$ .91	5.94 $\pm$ .91	5.92 $\pm$ .91
12	-10	6.13 $\pm$ .91	5.44 $\pm$ .91	4.48 $\pm$ .91
	0	4.40 $\pm$ .91	5.60 $\pm$ .91	6.73 $\pm$ .91

<sup>a</sup>Interaction significant ( $P < .05$ ) by analysis of variance, but not by HSD. Mean  $\pm$  S.E.



Table 296. Interaction effect of storage time (nine, twelve months), initial storage temperature and rate of freezing on percent fat in cooked beef roasts - data adjusted for differences prior to freezing

Evaluation time, month	Initial storage temperature, °F	Freezing rate, hours to 0°F		
		48	72	96
9	-10	6.15 + .91ab	8.35 + .91a	5.37 + .91ab
	0	7.52 + .91ab	5.99 + .91ab	6.63 + .91ab
12	-10	5.73 + .91ab	5.95 + .91ab	4.87 + .91ab
	0	2.89 + .91b	5.65 + .91ab	7.44 + .91ab

ab Any mean comparison with the same letters is not different ( $P > .05$ ). Mean + S.E.





The final sets of tables pertain to a calculated value of expressible moisture in raw and cooked beef roasts. The value has no specific units, but the higher the value, the more expressible (or "free") moisture. Respective to raw samples, differences in a general sense among project variables were not large (Table 297). After six months storage, roasts stored at 0°F final temperature had more expressible moisture than roasts stored at -10°F (Table 298). At nine months of frozen storage, the use of 0°F initial temperature produced more expressible moisture than -10°F, but only for roasts frozen to 0°F in 24 hr (Table 299). Temperature abuse created less expressible moisture in roast samples than nonabuse for roasts frozen to 0°F in 96 hr when evaluations occurred after twelve months storage (Table 300).

Freezing, itself, reduced expressible moisture as did twelve vs nine months of storage (Table 301). In an interaction of storage time and initial storage temperature, nine months storage increased expressible moisture in samples over six months storage, but only for roasts subjected to 0°F initial storage (Table 302). In an interaction involving storage time (immediately following freezing, twelve months), initial and final storage temperature and freezing rate, the major difference appeared to be really at twelve months, within the 0°F initial and final storage temperature, where 0°F in 48 hr produced lower expressible moisture than 0°F in 96 hr (Table 303).

Expressible moisture values for cooked beef roasts also showed few major differences (Table 304). Immediately following freezing, 0°F in 72 hr freezing rate produced more expressible moisture than 0°F in 96 hr, while following nine months storage, 0°F in 24 hr generated more expressible moisture in cooked roasts than 0°F in 72 hr (Table 305).



Table 297. General table illustrating the expressible moisture in raw beef roasts throughout storage times and according to final storage temperature and rate of freezing - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		.015 ± .0018	.014 ± .001	.015 ± .0013	.015 ± .0012
Immediately after freezing, 1 day		.015 ± .0008	.013 ± .0024	.013 ± .001	.014 ± .0007
6 months	-10T	.014 ± .0015	.014 ± .0022	.013 ± .0016	.013 ± .0018
	0T	.015 ± .0013	.014 ± .0011	.016 ± .0011	.015 ± .0014
	20T	.013 ± .0012	.014 ± .001	.014 ± .0011	.014 ± .0014
9 months	-10T	.015 ± .0024	.015 ± .0013	.015 ± .0016	.014 ± .0008
	0T	.014 ± .0010	.015 ± .002	.016 ± .0005	.014 ± .0012
	20T	.015 ± .0022	.015 ± .0019	.015 ± .0011	.014 ± .0008
12 months	-10T	.014 ± .0009	.014 ± .0007	.015 ± .0009	.013 ± .0006
	0T	.015 ± .0023	.014 ± .0012	.014 ± .0017	.015 ± .0027
	20T	.014 ± .0012	.014 ± .0003	.015 ± .0012	.013 ± .0011
	20N	.016 ± .0009	.014 ± .0018	.014 ± .0004	.016 ± .0012

<sup>a</sup>Mean ± S.D.; T = Temperature abused; N = Not temperature abused.



Table 298. Effect of final storage temperature on expressible moisture in raw beef roasts following six months storage

Final storage temperature, °F		
-10	0	20
.0135 ± .00034b	.0148 ± .00034a	.0139 ± .00034ab

ab Means on the same line with the same letters are not different ( $P > .05$ ); Mean ± S.E.



Table 299. Interaction effect of initial storage temperature and rate of freezing on expressible moisture in raw beef roasts following nine months storage

Initial storage temperature, °F	Freezing rate, hours to 0°F			
	24	48	72	96
-10	.013 $\pm$ .00051b	.014 $\pm$ .00051ab	.015 $\pm$ .00051ab	.014 $\pm$ .00051ab
0	.016 $\pm$ .00051a	.016 $\pm$ .00051a	.015 $\pm$ .00051ab	.014 $\pm$ .00051ab

ab Any mean comparison with the same letters is not different ( $P > .05$ ); Mean  $\pm$  S.E.





Table 300. Interaction effect of temperature abuse and rate of freezing on expressible moisture in raw beef roasts following twelve months of storage

Temperature abuse	Freezing rate, hours to 0°F			
	24	48	72	96
T	.014 $\pm$ .00062ab	.014 $\pm$ .00062ab	.015 $\pm$ .00062ab	.013 $\pm$ .00062b
N	.016 $\pm$ .00062ab	.014 $\pm$ .00062ab	.014 $\pm$ .00062ab	.016 $\pm$ .00062a

ab Any mean comparison with the same letters is not different ( $P > .05$ ); Mean  $\pm$  S.E.;  
 T = Temperature abused; N = Not temperature abused.

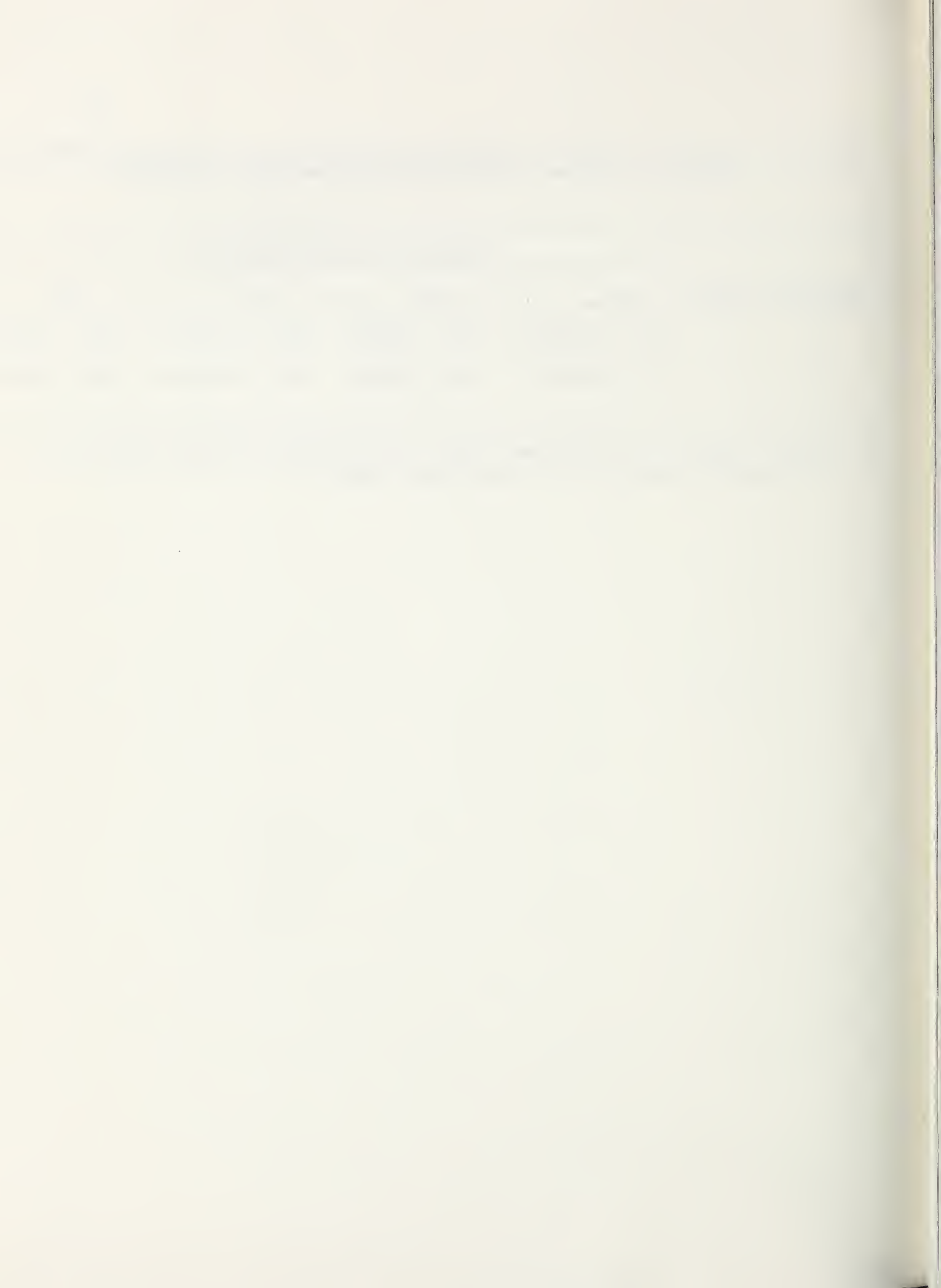


Table 301. Effect of various storage time comparisons on expressible moisture in raw beef roasts

Evaluation times	
Before freezing	Immediately following freezing, 1 day
.015 $\pm$ .00025a	.014 $\pm$ .00025b
9 months	12 months
.015 $\pm$ .00017a	.014 $\pm$ .00017b

ab Differences between means on the same line are significant ( $P < .05$ ); Mean  $\pm$  S.E.

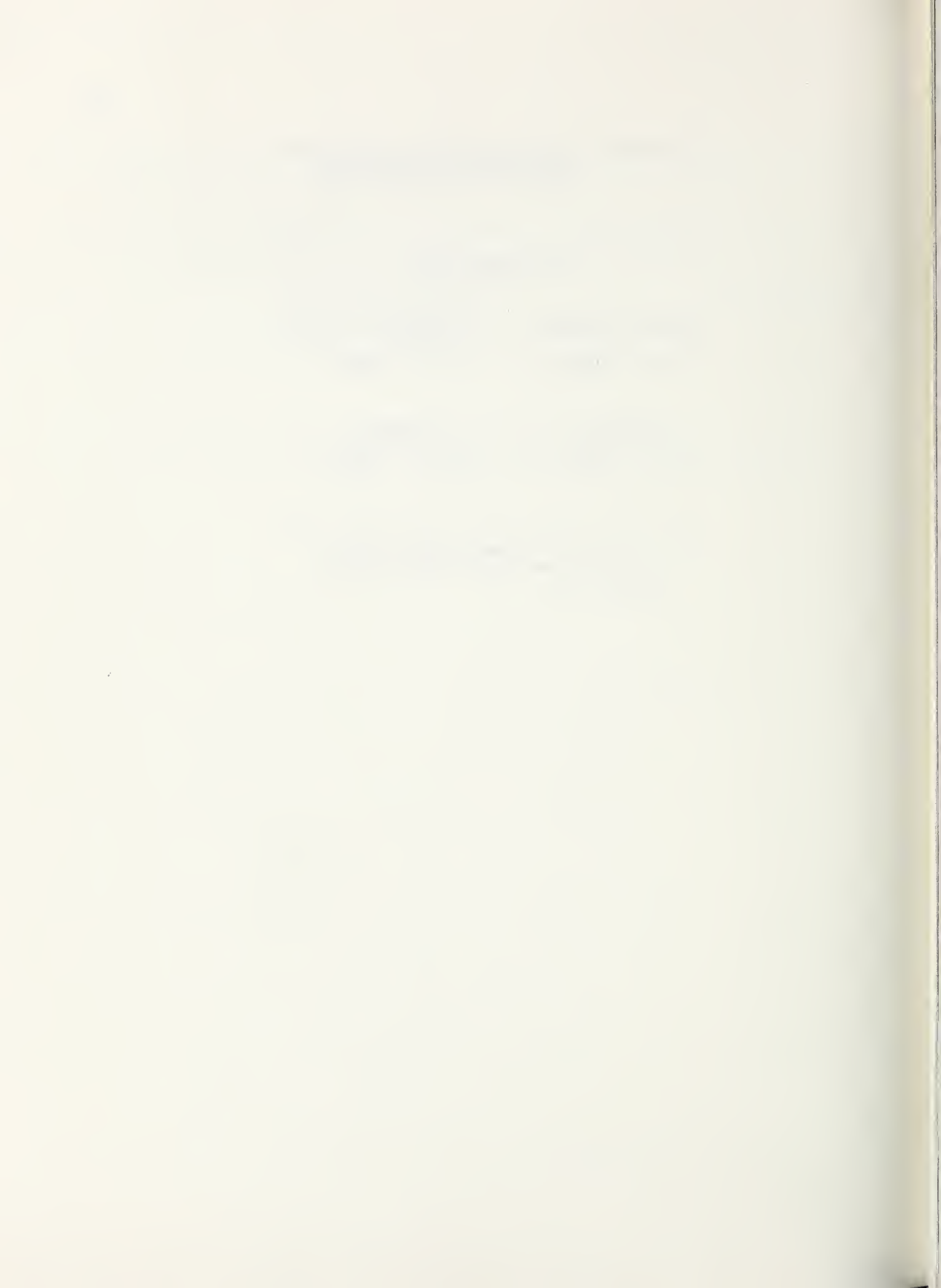


Table 302. Interaction effect of storage time (six, nine months) and initial storage temperature on expressible moisture in raw beef roasts

Evaluation time, months	Initial storage temperature, 0°F	
	-10	0
6	.014 $\pm$ .0003b	.014 $\pm$ .0003b
9	.014 $\pm$ .0003b	.015 $\pm$ .0003a

ab Any mean comparison with the same letter is not different ( $P > .05$ ); Mean  $\pm$  S.E.

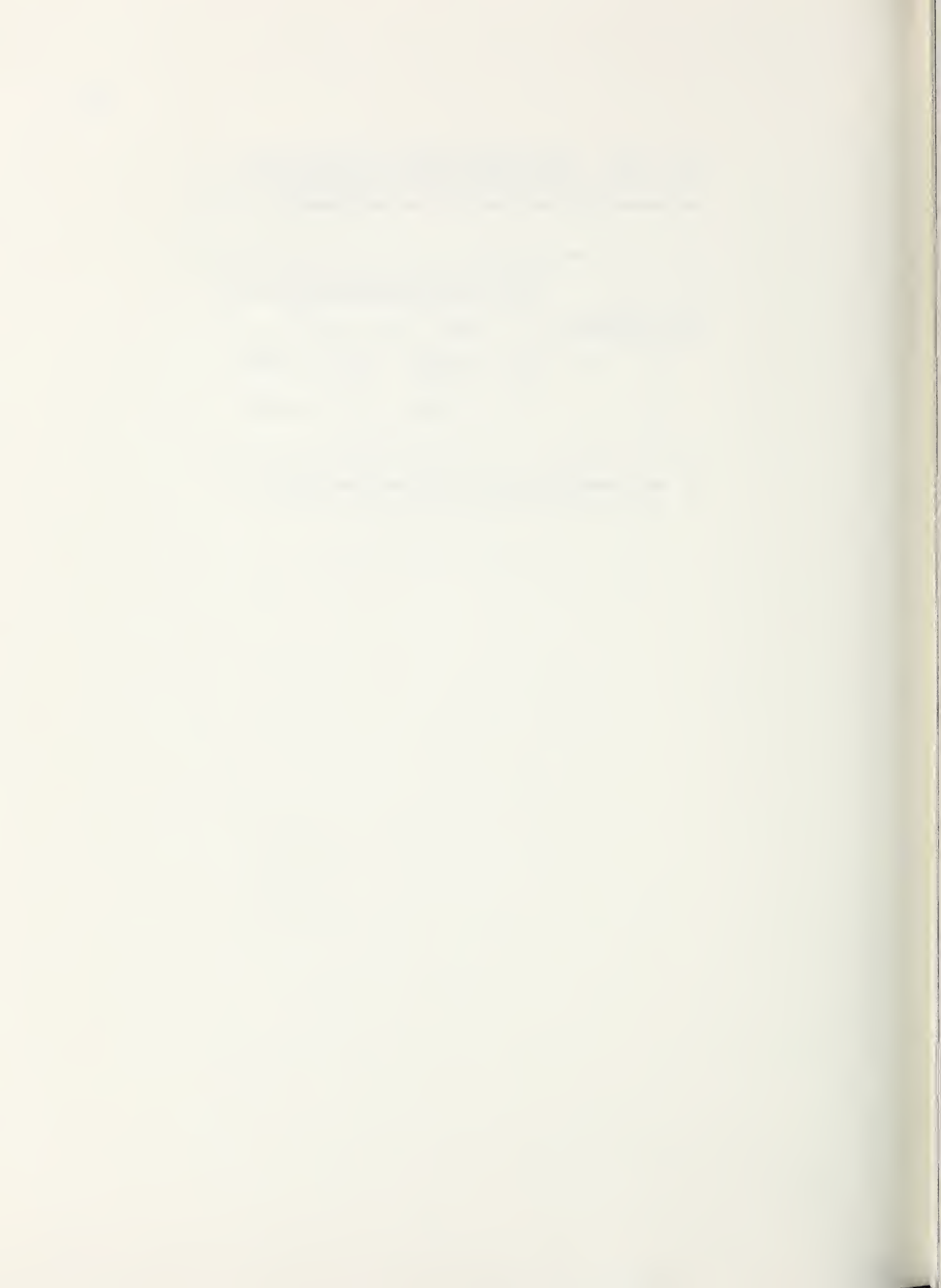


Table 303. Interaction effect of storage time (immediately following freezing, twelve months), initial storage temperature, final storage temperature and rate of freezing on expressible moisture in raw beef roasts

Evaluation time	Initial storage temperature, °F	Final storage temperature, °F	Freezing rate, hours to °F			
			24	48	72	96
Immediately after freezing, 1 day			.015 + _	.013 + _	.014 + _	.014 + _
12 months	-10		.015 + _	.013 + _	.014 + _	.014 + _
		-10	.014 + _	.015 + _	.015 + _	.013 + _
		0	.015 + _	.015 + _	.014 + _	.013 + _
	20		.014 + _	.015 + _	.016 + _	.013 + _
		20	.014 + _	.015 + _	.016 + _	.013 + _
			.014 + _	.015 + _	.015 + _	.013 + _
12 months	0		.014 + _	.013 + _	.015 + _	.013 + _
		-10	.016 + _	.012 + _	.015 + _	.017 + _
		0	.015 + _	.013 + _	.015 + _	.013 + _
	20		.015 + _	.013 + _	.015 + _	.013 + _
		20	.015 + _	.013 + _	.015 + _	.013 + _
			.015 + _	.013 + _	.015 + _	.013 + _

abc Any mean comparisons with the same letters are not different ( $P > .05$ ); Mean + S.E.

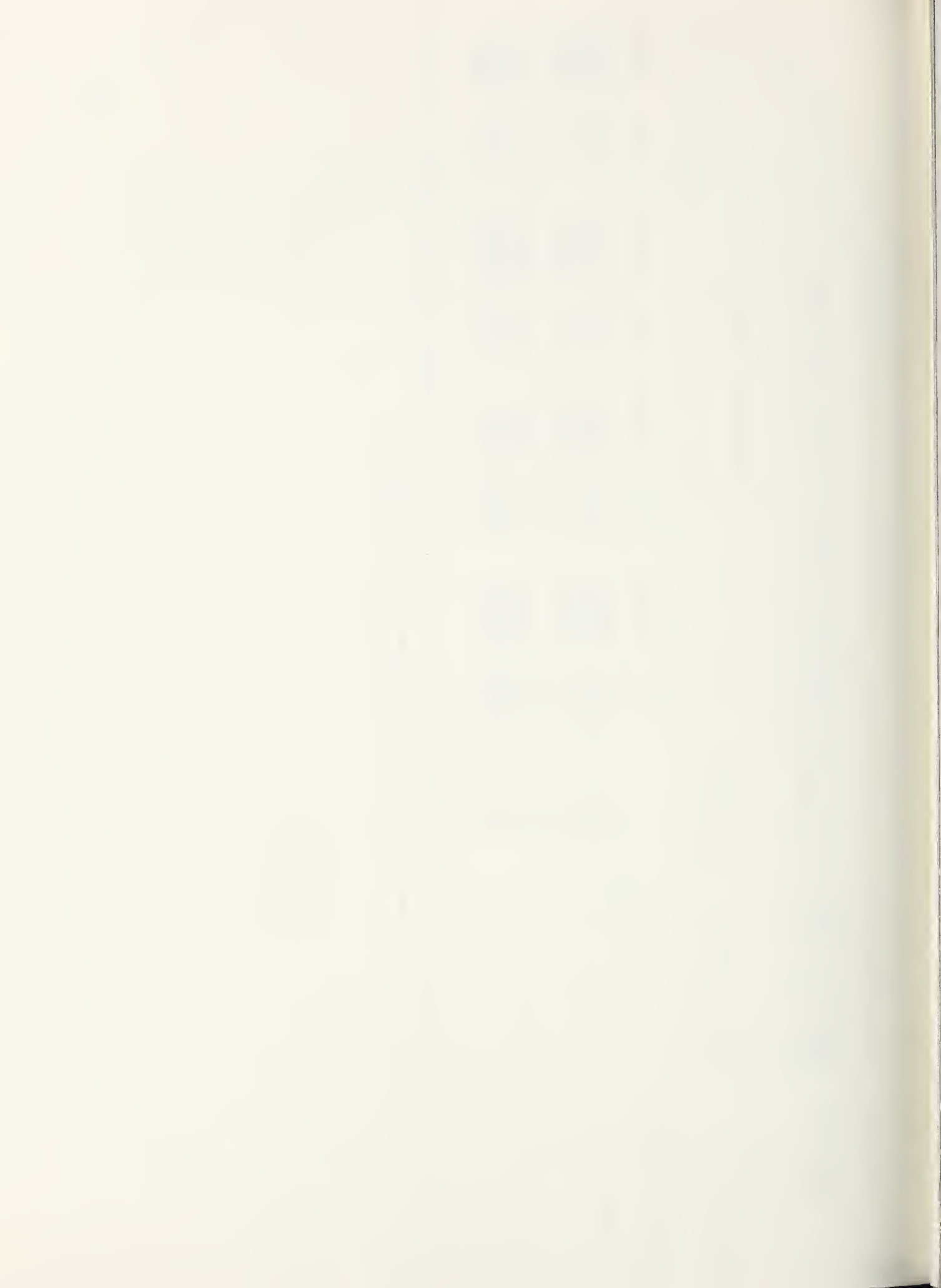




Table 304. General table illustrating the expressible moisture in cooked beef roasts throughout storage times and according to final storage temperature and rate of freezing - no statistical analyses<sup>a</sup>

Evaluation time	Final storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Before freezing		.016 + .001	.017 + .0014	.018 + .0014	.016 + .0011
Immediately after freezing, 1 day		.015 + .0017	.016 + .0009	.017 + .0017	.015 + .001
6 months	-10T	.017 + .0009	.014 + .0017	.015 + .0016	.017 + .0016
	0T	.016 + .0008	.016 + .0008	.016 + .0005	.016 + .0007
	20T	.015 + .0005	.016 + .0019	.015 + .0014	.017 + .0017
9 months	-10T	.018 + .0008	.015 + .002	.016 + .0023	.016 + .0011
	0T	.018 + .0014	.017 + .0009	.017 + .0007	.017 + .001
	20T	.019 + .0014	.017 + .0008	.016 + .0006	.016 + .0004
12 months	-10T	.018 + .0021	.017 + .0007	.018 + .0008	.017 + .001
	0T	.016 + .0003	.018 + .0017	.018 + .0008	.018 + .0018
	20T	.017 + .0014	.016 + .0008	.018 + .0029	.014 + .0043
	20N	.018 + .0025	.016 + .0017	.016 + .0008	.017 + .0015

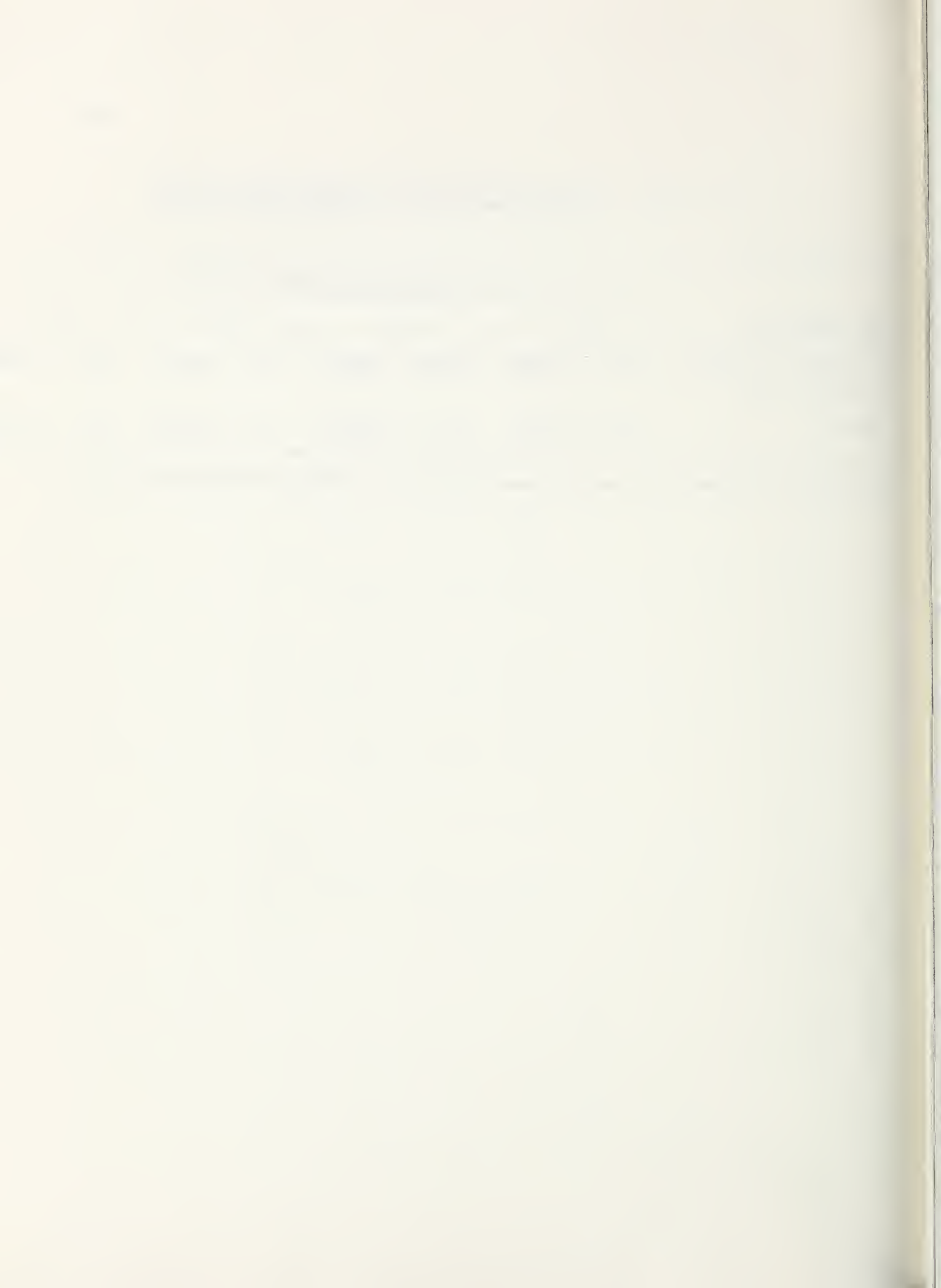
<sup>a</sup>Mean + S.D.; T = Temperature abused; N = Not temperature abused.



Table 305. Effect of freezing rate on expressible moisture  
in cooked beef roasts at various storage times

Evaluation time	Freezing rate, hours to °F			
	24	48	72	96
Immediately following freezing, 1 day	.0151 $\pm$ .0005ab	.0159 $\pm$ .0005ab	.0167 $\pm$ .0005a	.0146 $\pm$ .0005b
9 months	.018 $\pm$ .0004a	.017 $\pm$ .0004ab	.017 $\pm$ .0004b	.017 $\pm$ .0004ab

ab Means on the same line with different letters are different ( $P < .05$ ); Mean  $\pm$  S.E.



Freezing, itself, reduced expressible moisture, but storage increased the values for cooked roasts (Table 306). After nine months storage,  $-10^{\circ}\text{F}$  initial storage temperature elevated expressible moisture over that noted immediately following freezing, but only for roasts frozen to  $0^{\circ}\text{F}$  in 24 hr (Table 307).



Table 306. Effect of various storage time comparisons on expressible moisture in cooked beef roasts

Evaluation times	
Before freezing	Immediately following freezing, 1 day
.017 $\pm$ .00026a	.016 $\pm$ .00024b
Immediately following freezing, 1 day	9 months
.0157 $\pm$ .00042	.0174 $\pm$ .00042
Immediately following freezing, 1 day	12 months
.0157 $\pm$ .00046b	.0172 $\pm$ .00046a
6 months	9 months
.016 $\pm$ .00024b	.017 $\pm$ .00024a

ab Differences between means on the same line are significant ( $P < .05$ ); Mean  $\pm$  S.E.





Table 307. Interaction effect of storage time (immediately following freezing, nine months), initial storage temperature and freezing rate on expressible moisture in cooked beef roasts

Evaluation time	Initial storage temperature, °F	Freezing rate, hours to 0°F			
		24	48	72	96
Immediately after freezing, 1 day		.015 + .00048b	.015 + .00048b	.017 + .00048ab	.015 + .00048b
9 months	-10	.019 + .00084a	.016 + .00084ab	.016 + .00084ab	.017 + .00084ab
	0	.018 + .00084ab	.017 + .00084ab	.017 + .00084ab	.018 + .00084ab

ab Any mean comparison with the same letters is not different ( $P > .05$ ); Mean +  $\pm$  S.E.



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